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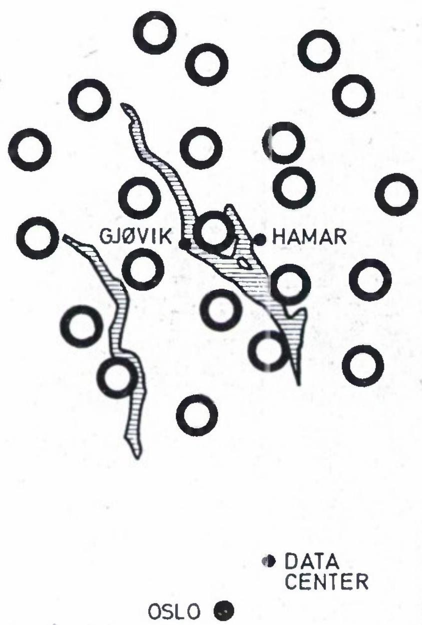

NORWEGIAN SEISMIC ARRAY

NORSAR

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ARRAY MONITORING AND FIELD MAINTENANCE REPORT
1/10-1971 - 30/6-1972

by

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8 November 1972

The NORSAR research project has been sponsored by the United States of America under the overall direction of the Advanced Research Projects Agency and the technical management of Electronic Systems Division, Air Force Systems Command, through Contract No. F19628-70-C-0283 with the Royal Norwegian Council for Scientific and Industrial Research.

This report has been reviewed and is approved.

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ABBREVIATIONS

ADC	-	Analog-to-Digital Converter
AM	-	Array Monitoring
ATC	-	Alternate Telemetry Command/EOC
BE card	-	Lightning Protection Card
CCB	-	NORSAR Change and Control Board
CTV	-	Central Terminal Vault
DP	-	Detection Processor
EOC	-	Experimental Operations Console
EP	-	Event Processor
EPU	-	SLEM External Power Unit
FMC	-	Field Maintenance Center (Brumunddal)
LP	-	Long Period
LPV	-	LP Sensor Vault
LTA	-	Line Termination Attenuator
MC	-	Maintenance Center (Kjeller)
NDPC	-	NORSAR Data Processing Center
RA-5	-	SP seismograph amplifier
RCD	-	Remote Centering Device
RSA/ADC	-	Range Scaling Amplifier/ADC
SLEM	-	Short and Long Period Electronic Module
SP	-	Short Period
SPS	-	Special Processing System
WHV	-	Well Head Vault

SUMMARY

The improvement, maintenance and operation monitoring of NORSAR are today taken care of by a department of the NORSAR project organization, headed by personnel at the NORSAR Data Center. The monitoring of the array performance is done remotely, at the Data Center, using a program package with a large number of on-line and off-line features.

The report, covering the period 1 October 1971 - 30 June 1972, discusses the field maintenance of the array, the remote array monitoring and their interaction. The routines for the maintenance and monitoring tasks, and the monitoring program package are described.

With only a few exceptions, all parts of the array field instrumentation have operated satisfactorily with less malfunctioning than expected. The most sensitive parts of the system are the SP seismometer and the A/D converters.

1. INTRODUCTION

The work presented in the report relates to the tasks of monitoring and maintaining the field installations of the Norwegian Seismic Array (NORSAR). This field of work has developed to include responsibility also for proper maintenance of modems and communications lines between modems at the 22 subarrays and the NORSAR Data Center (NDPC). The network is maintained in cooperation with subcontractor NTA (Norwegian Telegraph Administration). The work, consisting of remote array monitoring performed at NDPC, array maintenance performed by the NORSAR field technicians and communication tasks, will later be labeled "AM" or "AM work". All task objectives indicated in the report were accomplished during the period 1 October 1971 - 30 June 1972, and are detailed in subsequent sections.

Appendix I includes a brief description of the features of the program system used in the monitoring of the array. Appendix II lists the instrumentation used for routine workshop and field maintenance, and the tolerances of the NORSAR field equipment are presented in Appendix III.

1.1 Objectives

The work is defined in contract number F19628-70-C-0283 entered between U.S. Department of the Air Force/ESD and the Royal Norwegian Council for Scientific and Industrial Research (NTNF). The contract objectives for AM are:

Task 1: Maintenance of NORSAR subarrays

a) Develop and perform a preventive and corrective field maintenance program that is integrated with the NDPC remote calibration and maintenance analysis capability. This maintenance program will include all 22 subarrays with their physical facilities such as seismometers, intra-subarray communications, electronics, instrumentation, power supplies, vaults and access roads. This program will include repair, calibration and replacement of defective subarray components.

b) Provide and maintain workshop facilities for the repair of subarray equipment.

c) Keep detailed records containing work history on subarrays and components, component repair history, failure rates and other pertinent data.

Task 2: Remote array monitoring at NDPC

a) Establish procedures for array monitoring (AM) operation and AM reporting. These procedures will include array monitoring and calibration, routine maintenance

and emergency array maintenance actions that are an integral part of the NDPC operation.

b) Evaluate array performance, monitor array status and direct the subarray maintenance (conduct routine array calibration and array operations verification using the NDPC AM diagnostics.)

c) Maintain the NORSAR AM computer programs. This will include analysis, correction and testing of errors and improvements.

d) Establish and maintain procedures and records that indicate all equipment utilization and performance relevant to AM. This includes periferal support equipment and field equipment where data is gathered by the NDPC operation as part of array calibration, status monitoring and field maintenance assistance.

Task 3: Maintenance of data transmission network

a) Maintenance of data communication circuits from each subarray to NDPC.

b) Maintenance of data modems.

1.2 Background

Prior to the time when NTNF took over the administration of the NORSAR project 1 July 1970 and until 1 October 1971, the maintenance of NORSAR field installations and equipment was accomplished by Noratom-Norcontrol A/S on a subcontract, NTNF/NORSAR Order No. 1, of Contract F19628-70-C-0283. During the period 1 July 1970 - 1 October 1971 the field maintenance personnel consisted of 10 persons - 9 technicians and a manager. Six men were located at the field maintenance center (FMC) at Brumunddal near the center of the array, two at the NORSAR maintenance center (MC) at Kjeller near the NORSAR Data Center (NDPC), and two at the company's headquarters in Oslo.

In cooperation with IBM/FSD personnel implementing the NORSAR computer systems at NDPC, NDPC personnel started a limited array monitoring in December 1970 using the programs available at that time. This work was developed and accomplished in addition to the on-site monitoring and maintenance performed by Noratom-Norcontrol A/S.

As a result of increased experience of the NDPC personnel assigned to array monitoring NDPC became involved in the direction of the array maintenance tasks. Simultaneously, with the establishment of a group of AM analysts at NDPC during the first half of 1971, more AM programs with advanced features became available. On 1 October 1971 the contract between NTNF and Noratom-Norcontrol A/S for maintaining the array was terminated. From then on NTNF assumed the direct task responsibilities and technical direction of maintaining, operating and improving the NORSAR field installations. Eight of the field technicians employed by Noratom-Norcontrol A/S and located at MC and FMC were transferred to NTNF, continuing their previous work under the new administration.

1.3 AM Personnel

The AM group consisted of 8 persons on full time - six field technicians at FMC, one AM analyst heading the group and his assistant. The AM analysts were assisted by one person not belonging to the AM group, who was monitoring and maintaining the communications network.

The field personnel have been organized with one of the technicians as a manager at the FMC. He cooperates closely with the AM analysts and reports to these. The field maintenance work to be accomplished is decided upon in conjunction with him to secure a satisfactory exploitation of available manpower.

The activities at MC/Kjeller accomplished in the period are discussed in (1) and (2).

2 NDPC AM OPERATING PLAN

Reference (3) includes an outline of the AM system failures the instrument characteristics tested by NDPC computer programs used in array monitoring, and the scheduled monitoring activities at NDPC.

A brief summary of the AM programs used in the monitoring is given in Appendix I. The activation rates for the different AM programs have been modified during the period. They are discussed in Section 2.1. Procedures at NDPC for handling AM data, reporting and cooperating with field personnel are briefly discussed in Section 2.2.

2.1 Scheduled Monitoring

2.1.1 Monitoring rates

During the reporting period only minor modifications to the schedule for remote array monitoring have taken place (see Table 2.2). The array monitoring schedule as of 30 June 1972 is shown in Table 2.1. As will be seen, all AM programs are activated at least once in an eight-week interval.

The chosen monitoring frequency of a subarray using a certain AM program has been reviewed regularly. The rates have been set based on:

1) Experiences of accuracy and reliability of the program.
2) The error rate of or drift in units monitored by the program.
3) Computer time requirement of the program.
4) The general load on the NDPC computer.

Program Name (AM)		No. of Weeks in Cycle							
		1	2	3	4	5	6	7	8
CHANEV	SP	A	B	C	D	A	B	C	D
	LP	AB	CD			AB	CD		
SACP	SP	A	B	C	D	A	B	C	D
	LP			AB	CD			AB	CD
LPCAL		AB	CD	AB	CD	AB	CD	AB	CD
SLEMTEST		AB	CD	AB	CD	AB	CD	AB	CD
MISNO		A	B	C	D	A	B	C	D
CSCONTROL		ABCD	ABCD	ABCD	ABCD	ABCD	ABCD	ABCD	ABCD

SA Partition Codes:

A : 01A - 05B
B : 06B - 03C
C : 04C - 09C
D : 10C - 14C

Table 2.1
NORSAR AM Schedule

The routine monitoring rates of any subarray in the period using the monitoring programs are shown in Table 2.2 (see also Table 2.1).

Program	Rate 1	Rate 2
CSCONTROL	Weekly	
LPCAL	Biweekly	
SLEMTEST	4th week until Dec 1971	Biweekly thereafter
MISNO	4th week (initiated Nov 71)	
CHANEVSP CHANEVLP	4th week	
SACPSP SACPLP	4th week until Feb 1972	8th week thereafter

Table 2.2
Remote Monitoring Rate per Subarray.

2.1.2 Discussion on rates and programs

2.1.2.1 CSCONTROL

The program is used in conjunction with the transmission error rate as indicated by the ICW and ODW poly and synchronization codes, displayed on DP printout. The error rate indications are calculated over 16½-minute intervals and printed out. This information allows a frequent and quick control of the performance of the different telephone lines between subarrays and NDPC.

The objective of program CSCONTROL is control of the line using the looping circuits along the individual lines. The program has been advantageous to control transmission line quality concerning phase and gain of line carrier signal. The reason is that the program's tolerance

requirements to satisfactory transmission of test pattern along the lines are tighter than those requested by the NDPC and SLEM electronics. CSCONTROL results are therefore used as a first indicator for deteriorating line performance.

2.1.2.2 LPCAL

The activation rate of the program has been constant throughout the period. As expected, a much faster drift in the mass equilibrium position (MP) and the free period (FP) of the LP instruments has been observed on most of the instruments during March and April (see Figures 3.34 to 3.39). However, biweekly monitoring and calibration have been found satsifactory.

2.1.2.3 SLEMTEST

The number of ADCs observed faulty or out of adjustment during the last half of 1971 resulted in a change of the monitoring rate to reduce the possible time of malfunctioning in these units. Another reason for change in rate was a need for increased confidence in the SLEM test generators. A faulty or non-adjusted generator in the SLEM may result in misleading results of CHANEV if the program is not cancelled.

2.1.2.4 MISNO

While the program SLEMTEST tests the RSA/ADC for one input voltage, the MISNO program controls the performance in a wide range of voltages. Both tests have been found satisfactory for their use, but the off-line processing time required by MISNO limits its availability (see Table 2.3).

2.1.2.5 CHANEVSP/LP

These two programs determine very accurately the characteristics of the transfer functions for both SP and LP data channels. They are by far the most important and

advanced programs in the AM program package. However, the time required for a total subarray analysis is considerable (see Table 2.3).

2.1.2.6 SACPSP/LP

These are preferable for measuring the degree of distortion, i.e., generation of higher signal harmonics of the input, in the data channel units. The occurrence of this effect was less than expected and the monitoring rate was relaxed in February 1972. From 1 April 1971 to 31 January 1972 the total number of disclosures of distortion in any SP unit (seismometer, Ra-5, LTA) was 12. As a result of RA-5 maintenance and replacement of seismometers during fall 1971, the number of distortions disclosed during the period 1 February to 30 June 1972 was reduced to 3. The SACPLP has disclosed no distortions in any unit in the LP channels during the period.

2.1.2.7 Evaluation

An evaluation of the AM system conducted by IBM/FSD in cooperation with AM analysts was accomplished during winter 1971/72. The primary aim of the study was to show consistency between the on-line and off-line measurement techniques and field measurements, as well as to provide an overall measure of the accuracy and usefulness of each technique.

Since the AM relies heavily on the channel analysis performed by CHANEVSP and CHANEVLP, efforts were made to verify the outputs of these. Validation of the channel characteristics calculated by CHANEV programs was done by measuring the characteristics in the field and comparing them with the CHANEV results. For most parameters this technique was successful. A few discrepancies between field and program were discovered. The field measurements

disclosed that the values for LP instruments' damping coefficients were significantly higher than those calculated by CHANEVLP. This discrepancy was investigated more closely after the termination of the evaluation and was successfully explained.

Altogether it was found that based on these comparison, it was possible to make a valid judgement on how good the CHANEV outputs were as a function of the average per cent error computed by CHANEV. The work accomplished by IBM is documented in (4).

2.1.2.8 Time requirements

Table 2.3 shows the time requirements of the different AM programs for routine execution. Collection of a data base from a subarray for later off-line analysis is accomplished in parallel with the acquisition of seismic data from other subarrays. To the total amount of

Program	EOC/ ATC Code	Time req. pr. subarray pr. program execution (min.)		Total time req. pr. month (averaged) for total array: Data Collection		Data Analysis	
		Data Collection	Data Analys.	Hours	Minutes	Hours	Minutes
CSCONTROL	44	2	-	2	56		
LPCAL 1)	71	30	-	22	-		
SLEMTEST	04	85	-	62	20		
MISNO	48	35	20	12	50	7	20
CHANEVSP	11	25	35	9	10	12	50
CHANEVLP	16	80	45	29	20	16	30
SACPSP	26	10	20	1	50	3	40
SACPLP	31	50	46	9	10	8	26
Total off-line computer time = approx. 49 hours.							

Table 2.3

Computer Time Required by AM Programs.

off-line computer time required (49 hours per month) has to be added the time required for different types of ad hoc analysis and reruns of off-line programs erroneously executed. Roughly this adds another 4-5 hours.

2.1.3 Visual Inspection

To secure an acceptable quality of the data used in the seismic data processing at NDPC, the array status panel on the EOC was monitored daily. In addition, all sensor outputs were visually reviewed, using the EOC waveform display, to identify channels with deteriorating performance caused by abnormal amplitudes, spikes and other non-seismic noise. The frequency of this last test was relaxed in March to once every week. However, daily monitoring was resumed after a few weeks.

Starting in May all data channels were checked weekly for phase and gain failures, using the waveform display and inserting a sine wave of 1 Hz (SP) and 0.04 Hz (LP) at the calibration coil of the sensors.

Most of the subarrays (CTV/LPV facilities, permanent installations and environment) have been inspected once by the AM analysts in the period (Figure 2.1).

Other procedures to secure data integrity are:

1) Subarray checkout at NDPC before departure of the maintenance team after a visit. This consists of verbal status reporting by visitor, visual data channel check using the EOC, and SLEM circuit tests.

2) Emergency actions if array status alarms are lit on the EOC.

3) Regular logging of time intervals when any subarray has been masked, to survey loss of seismic data (initiated May 1972).

Year	Month	Subarrays																					
		01A	01B	02B	03B	04B	05B	06B	07B	01C	02C	03C	04C	05C	06C	07C	08C	09C	10C	11C	12C	13C	14C
1971	Oct																						
	Nov																	x	x		x	x	
	Dec						x	x	x														
1972	Jan																						
	Feb	x	x			x																	
	Mar																						
	Apr									x	x			x	x								
	May																						
	Jun			x																			

Figure 2.1 On Site Inspection of Subarrays.

2.2 AM Internal and External Reporting

All actions at NDPC related to AM tasks which interrupt the normal acquisition of seismic data from one or more subarrays are logged. A board located in the NDPC computer hall is kept permanently updated by AM analysts as a reference on array status for scientific and computer operator personnel.

The field maintenance personnel mail a daily report to NDPC on activities performed at the array sites. The reports are reviewed by AM analysts to get an on-the-spot evaluation of disclosed malfunctions and a comparison with scheduled maintenance tasks. This reporting also gives the necessary feed-back for control of reliability and interpretation of the AM system.

In addition, the field technicians issue a weekly and a monthly report discussing status of FMC and the array in general, and projects not covered by the daily reports.

Biweekly a report on LP system status is sent to ESD/TPO, and a review of all tasks accomplished by the AM group to the NORSAR change and control board (CCB).

A computerized report on all data channels giving the last available information on their performance is issued daily. This is based on the parameters calculated by the on-line and off-line AM programs. This reporting was initiated 26 May.

3 ARRAY MONITORING AND FIELD MAINTENANCE

This chapter includes a review of actions of remote array monitoring at NDPC and maintenance accomplished at the subarrays by the field technicians. A "subarray history"

for each site is given in Section 3.2. These figures will disclose the relation between NDPC array monitoring and the field maintenance activity. A discussion of faults or maintenance which are of a non-general type is given in 3.2.3. Repairs accomplished at the NORSAR workshops are outlined in 3.2.4. The stability and trend of the array field equipment are discussed in 3.2.5.

The principles for directing the maintenance of the array and the assignment of priorities to different types of equipment errors are briefly discussed in 3.1.

3.1 Maintenance Policy

The strength and flexibility of the AM system imply that only corrective and not preventive maintenance in general is a necessity in maintaining the operating parts of the array. The performance of the array is regularly, and in some ways continuously, controlled by NDPC. Therefore, the work program for personnel in the field and the assignment of priorities to the different maintenance jobs should depend on the AM analysts' interpretation of the output of the AM programs.

The field technicians are directed by the AM analysts to perform ad hoc operations at sites where malfunctions or deteriorating performance of instrumentation and electronics are disclosed. The number of visits to the different sites has been high enough to allow regular on-site inspection and satisfactory maintenance of facilities and installations, which cannot be monitored by NDPC.

We have comprehended that to establish a priority scheme which strictly tells in which sequence errors or groups of errors at different subarrays should be corrected does not give a satisfactory utilization of the available man-

power and expertise of the field technicians. There are different reasons for this. We have encouraged the technicians to specialize in certain technical sectors of their work. The advantage of this is obvious, but implies that the right man may not be accessible when needed. Secondly, it may be more advisable to let one maintenance team on the same day accomplish work at two subarrays located next to each other, both having "low priority" faults, instead of visiting one with "high priority" faults. Seasonal conditions and problems concerning access to the sites have to be considered, etc. Also, the variety of faults which are experienced during the array monitoring makes the establishment of a definite "threshold" for a maintenance visit to a site difficult.

Loss of data from a whole subarray will, if possible, initiate immediate action. Data loss or limited malfunctioning on one or a few channels of a subarray have to be judged against other tasks.

3.2 Subarray History

3.2.1 Figure presentation

Figures 3.1 to 3.22 show the interrelation for each subarray between the accomplishment of the remote array monitoring, types of errors disclosed, and the response in the field. Maintenance visits to the sites and corrections to the instrumentation performed by the field technicians are also shown.

The figure abbreviations are:

1) Progr.

Shows the relation between the planned and actual array monitoring schedule (refer Section 2.1.1). The codes refer to the SP and LP versions of the analysis programs and to programs used for checking the performance of the SLEM electronics. For programs LPCAL and CSCONTROL, the

actual schedule has been equal to planned schedule for all subarrays and is therefore not shown.

2) Visits.
Shows the time lag between when a maintenance visit has been planned and when it was accomplished.

3) Proj's.
Shows the accomplishment of works of preventive maintenance to be defined in the following:

"SP work" included

a) Replacement or, if possible, adjustment of SP seismometer with free period, damping and/or sensitivity outside tolerance limits (Refer (5) and (6)), as disclosed by AM.
b) Modification of RA-5 input cards to suppress 50 Hz noise (Refer (7)).
c) Control and maintenance of WHV facilities where sensor replacement occurred.
d) Removal of SP seismometer, cable and SP amplifier from the deep boreholes (60 m) in A and B ring.

"LP work" included

a) Maintenance of LPV constructions.
b) Painting of LPV interior (LP tanks, floor and ladder).
c) Pressure testing of seals at LPV and LP tanks.
d) Inspection and recalibration of LP sensor if necessary.
e) RCD maintenance.

"Constr." included control and maintenance of

a) CTV constructions.
b) CTV inventories.
c) CTV/LPV environment and access roads.

4) AM.

Displays malfunctions disclosed by the AM system in the data channels (SP: 1-6, LP: 7-9) or subarray electronics (SLEM) with reference to the faulty parameters. Note that some of the codes refer to phenomena which may occur more places in the data channel (see Table 3.1).

Channel unit parameter	Code	With reference to:				
		Sensor SP/LP	Amplifier RA-5/Ithaco	LTA	Whole Channel	SLEM
Damping ratio	λ	x				
Nat. Freq.	F_0	x				
Sensitivity	S	x				
Distortion	D	x	x	x		
Mass Position	MP	x				
Filter Characteristics	F		x	x		
Gain	G		x	x		
DC offset	DCO				x	
CM rejection	CMR			x		
Lightning Prot. card	BE				x	
A/D converter	ADC					x
Test Generators (BB, LP-, SP-sine)	Gen's					x

Table 3.1

Identification of data channel subsection where specified faults may occur (Refer figures 3.2 to 3.23).

The ACTION subsection tells which action has been accomplished during a maintenance visit (adjustment or replacement of faulty unit) with reference to the channel. Actions on the SLEM electronics are identified.

5) Rect/batt.
Refers to malfunctions disclosed in the rectifier and/or batteries.

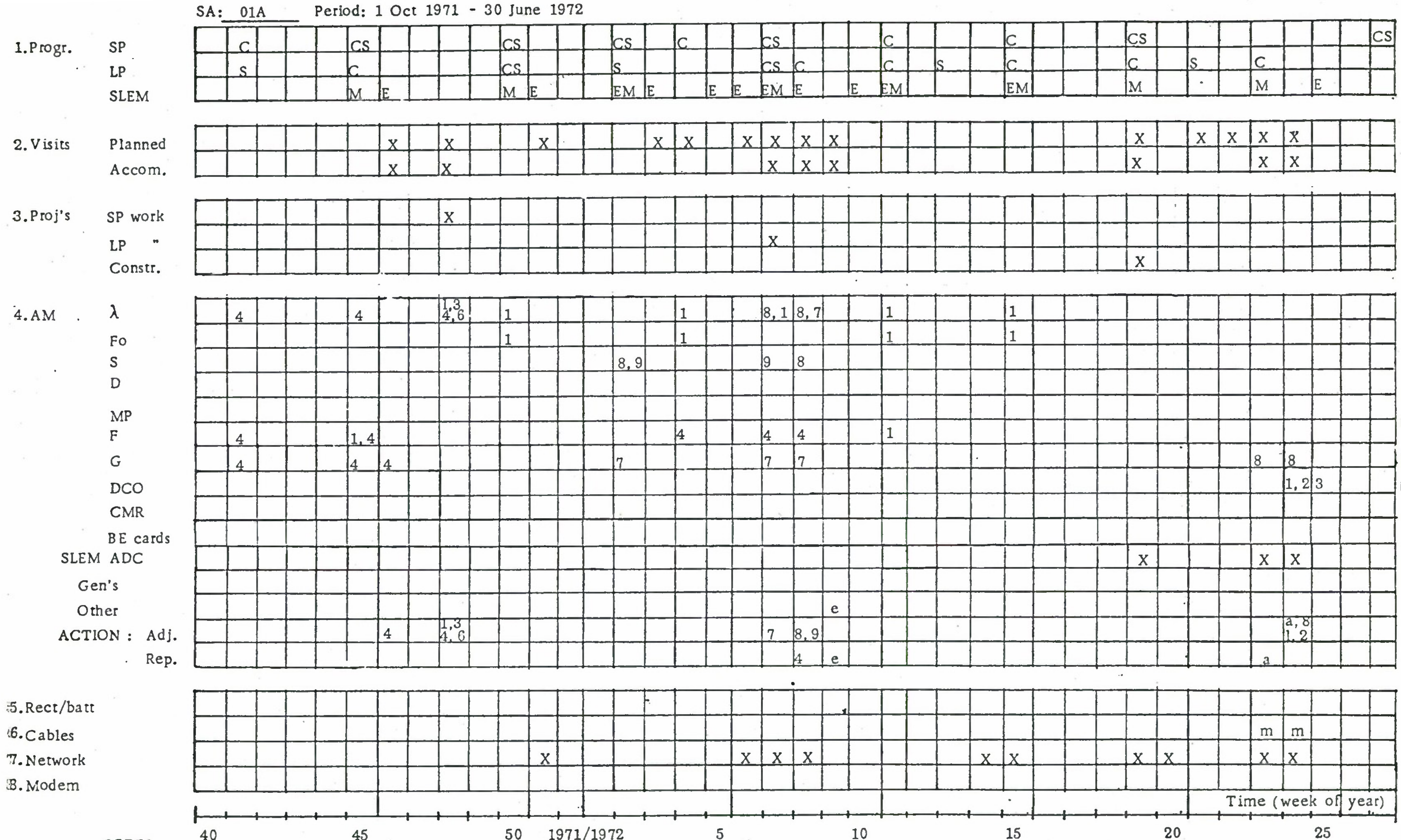
6) Cables.
Gives the time of occurrence of cable breakages of any seismometer or power cable and identifies the channel.

7) Sections Network and Modem.
Refer to faults disclosed in the communication system (telephone lines and CTV/NDPC modems).

3.2.2 Discussion

3.2.2.1 Subarray monitoring schedule

Figures 3.1 - 3.22, Figure Section 1, show that the planned schedule for the remote array monitoring has been well met. In a few cases where the monitoring has been interrupted, the reasons have been either intermittent high computer loads caused by high priority jobs as the EP, or cancellations of the AM program in question at signal insertion on all or most of the subarray's data channels. The cancellations of these programs are explained by hardware troubles such as degraded performance of the test signal generator and relays, or computer under- or overflow in the arithmetic calculations during the analysis of the acquired data base.



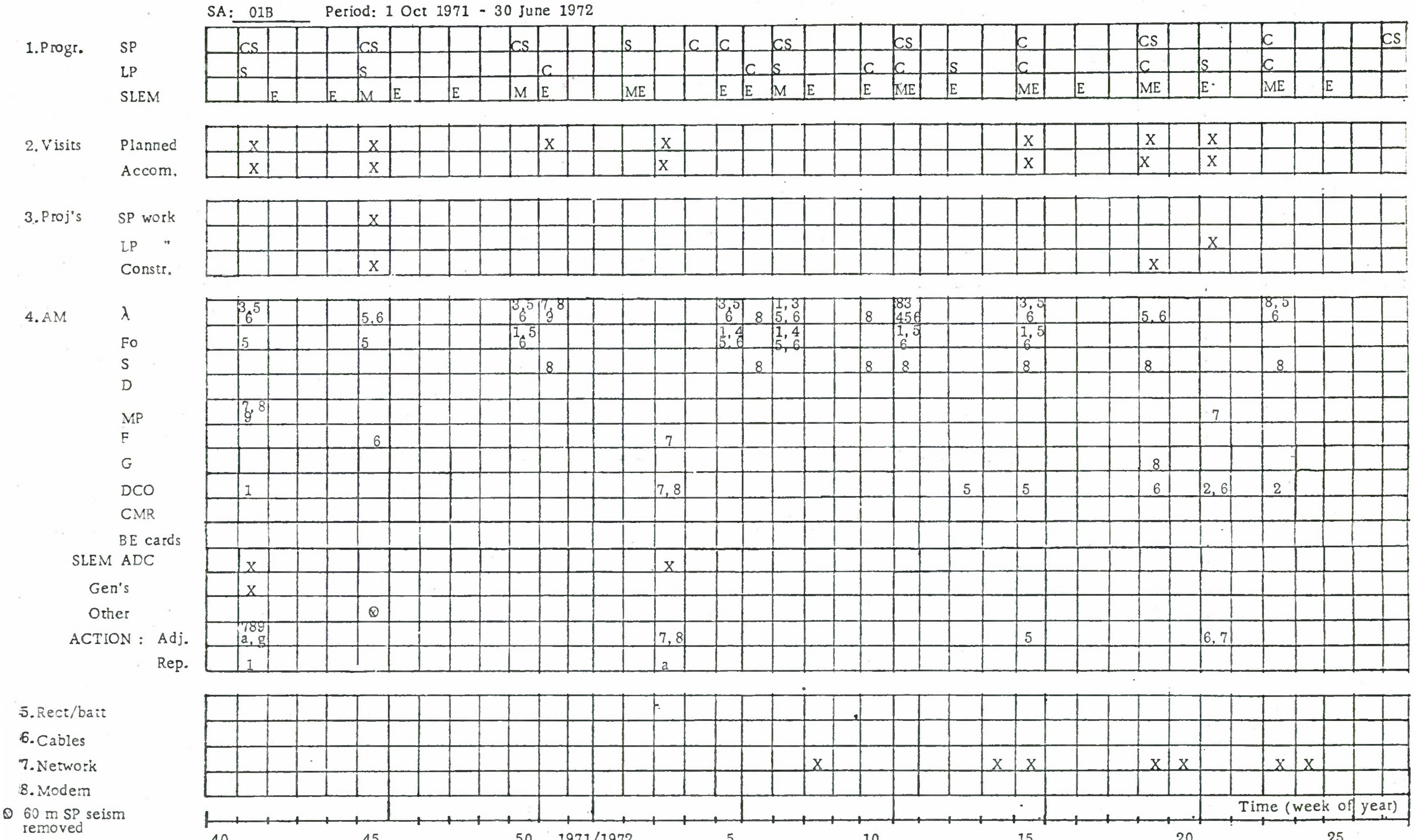
CODES

Programs: C - CHANEV
S - SACP
M - MISNO
E - SLEMTEST

Hardware/SLEM: e - EPU
a - RSA/ADC
g - Test Generators
m - Main data cable
p - Power cable

Figure 3.1

SUBARRAY HISTORY - Array Monitoring Disclosures



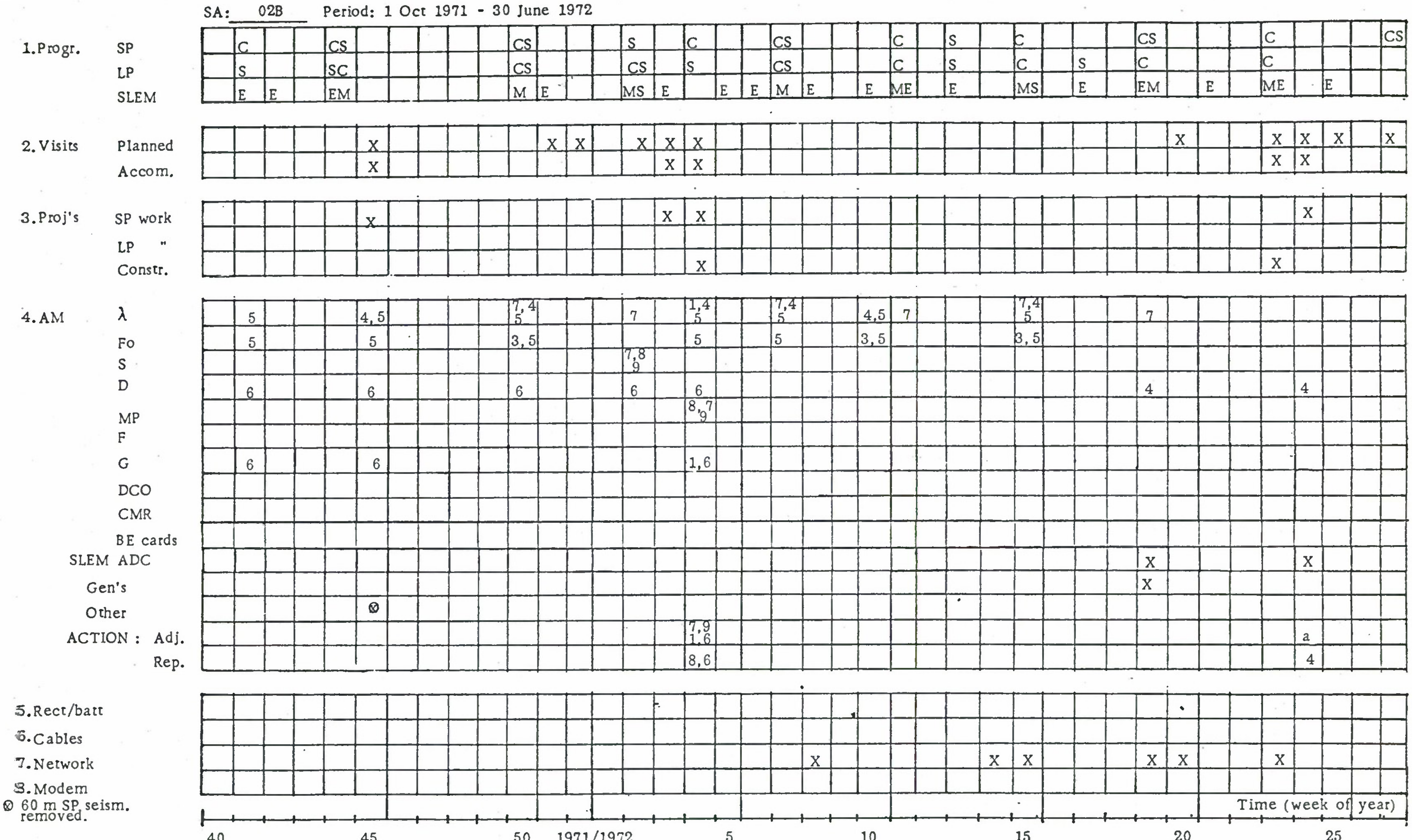
CODES

Programs: C - CHANEV
S - SACP

Hardware/SLEM: e - EPU
a - RSA/ADC

Figure 3.2

SUBARRAY HISTORY - Array Monitoring



CODES

Programs: C - CHANEV
S - SACP
M - MISNO
E - SLEMTEST

Hardware/SLEM: e - EPU
a - RSA/ADC
g - Test Generators
m - Main data cable
p - Power cable

Figure 3.3

SUBARRAY HISTORY - Array Monitoring Disclosures

SA: 03B Period: 1 Oct 1971 - 30 June 1972

		40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1.Progr.	SP		C				CS					SC				SC					SC				SC	C	C		C				C				C				CS
	LP						C					S	C			SC					SC				C		S		C				C		S		C				
	SLEM		E			E	M					M	E			E	EM		E	EM	M	E	M	E	EM	M	EM		EM		E		EM		E		ME				
2. Visits	Planned						X	X				X				X		X	X		X	X				X	X			X			X	X	X					X	
	Accom.						X	X				X				X			X		X	X				X	X			X			X	X	X					X	
3. Proj's	SP work						X	X								X																									
	LP "											X										X											X	X							
	Constr.																																	X	X						
4. AM	λ		3,6				3,6	3,6																	1,5		5														
	Fo																																8								
	S															9																									
	D																				4																				
	MP																																							9*	
	F																								2,6																
	G							123 56																	123 56				8				8								
	DCO																																		1		9,1				
	CMR															3	3		3	3																					
	BE cards																																								
	SLEM ADC																X		X		X		X		X	X															
	Gen's		X																X					X		X															
	Other						⊗																				DU			e											
	ACTION : Adj.							361 25											a,g							a,g	DU													9	
	Rep.							3,6													a,4									e			8								
5.Rect/batt																																									
6.Cables																																									
7.Network																						X						X	X				X	X			X				
8.Modem																																									

Time (week of year) — 1971/1972

* MP not adjustable coil stuck in magnet.

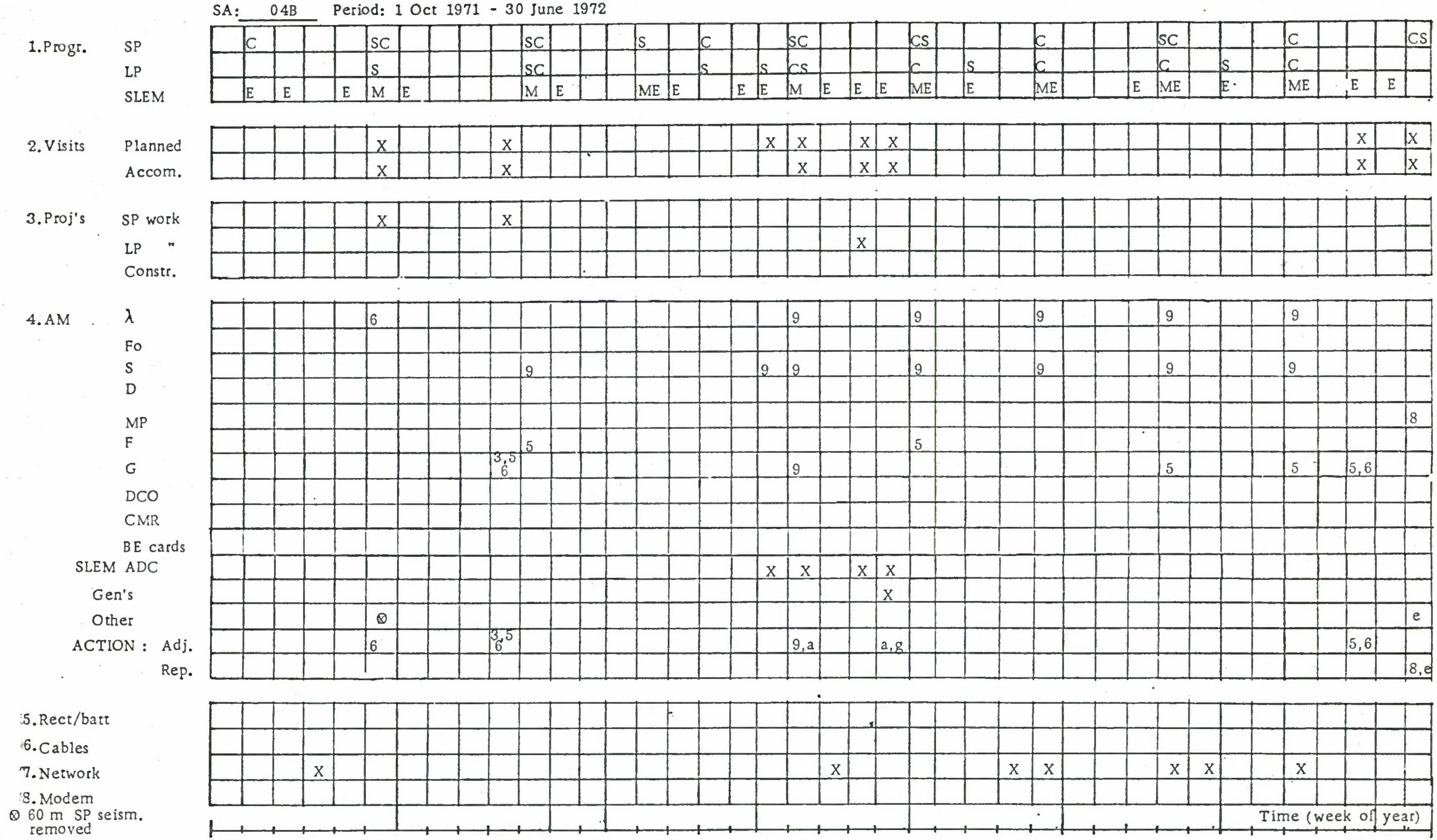
⊗ 60 m SP seism. removed

CODES

Programs: C - CHANEV Hardware/SLEM: e - EPU
S - SACP a - RSA/ADC

Figure 3.4

SUBARRAY HISTORY - Array Monitoring



CODES

Programs: C - CHANEV
S - SACP
M - MISNO
E - SLEMTEST

Hardware/SLEM: e - EPU
a - RSA/ADC
g - Test Generators
m - Main data cable
p - Power cable

Figure 3.5

SUBARRAY HISTORY - Array Monitoring Disclosures

SA: 05B Period: 1 Oct 1971 - 30 June 1972

		40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1.Progr.	SP		C				SC					SC				S		C			SC				CS				C				SC				C				CS
	LP						CS					CS				S		CS			CS				C	C	S		C	C			C		S		C	C			
	SLEM		E	E		E	M	E				M				EM	E		E	E	M	E		E	M	E	E		ME		E		ME		E		ME		E		
2.Visits	Planned					X		X									X							X													X	X	X	X	X
	Accom.					X		X									X							X													X	X	X		
3.Proj's	SP work							X																																	
	LP "																																								
	Constr.																																								
4.AM	λ		3,6				1,3 6					3,6						3,6			3,6				3,6				3,6				6								
	Fo		3,6				3,6					3,6						3,6			3,6				3,6				3,6				3,6								
	S						9					9						9							9	9			9	9			9				9	9			
	D																																								
	MP					8																		8																	
	F																																								
	G					134 56																																			
	DCO																																								
	CMR																																								
	BE cards																																								
	SLEM ADC																X																				X				
	Gen's		X			X											X																								
	Other							⊗																																	
	ACTION : Adj.					134 56g											a,g																				a				
	Rep.					8																		8																	
5.Rect/batt																																									
6.Cables																																						2	2	2	2
7.Network									X	X					X							X		X		X							X	X		X	X	X			X
8.Modem																																									

Time (week of year) — 1971/1972

⊗ 60 m SP seism. removed.

CODES

Programs: C - CHANEV, S - SACP

Hardware/SLEM: e - EPU, a - RSA/ADC

Figure 3.6

SUBARRAY HISTORY - Array Monitoring

SA: 06B Period: 1 Oct 1971 - 30 June 1972

1. [illegible]gr.	SP		S			SC		SC			C			SC				S	C			SC		C		S								SC							
	LP		S			S		CS				CS				S		C			C				C		S		C	C			C	S			C				
	SLEM			E		E		M	E		E		E	M		E	E	M	E	E		ME		E	E	M	E		E	M	E		E	M			E	M	E		E
2. Visits	Planned							X		X			X	X					X	X	X	X		X	X												X		X		
	Accom.							X		X			X												X														X		
3. Proj's	SP work							X		X																															
	LP "																																								
	Constr.																																								
4. AM	λ					2,4 6		234 56		2	6								1					1									7								
	Fo							2,3		2	6																														
	S					6		3,6																									7								
	D																																								
	MP																																								
	F							125 6											1,2			1,4 6		1,4 6																	
	G							123 45		3,1 2	2		6	2					2			1-6		1-6	1-6								7,9	1-6					1-6		
	DCO																																								
	CMR																																								
	BE cards																																						2		
	SLEM ADC																																						X		
	Gen's															X		X	X	X		X		X															X		
	Other							⊗																															e		
	ACTION : Adj.									1,2 3			6												1-6 g														1-6 g		
	Rep.									2,3																													2,5 a,e		
5. Rect/batt																																									
6. Cables																																									
7. Network									X	X					X			X				X		X		X							X	X		X	X	X		X	X
8. Modem																																									

Time (week of year)

40 45 50 1971/1972 5 10 15 20 25

⊗ 60 m SP seism. removed.

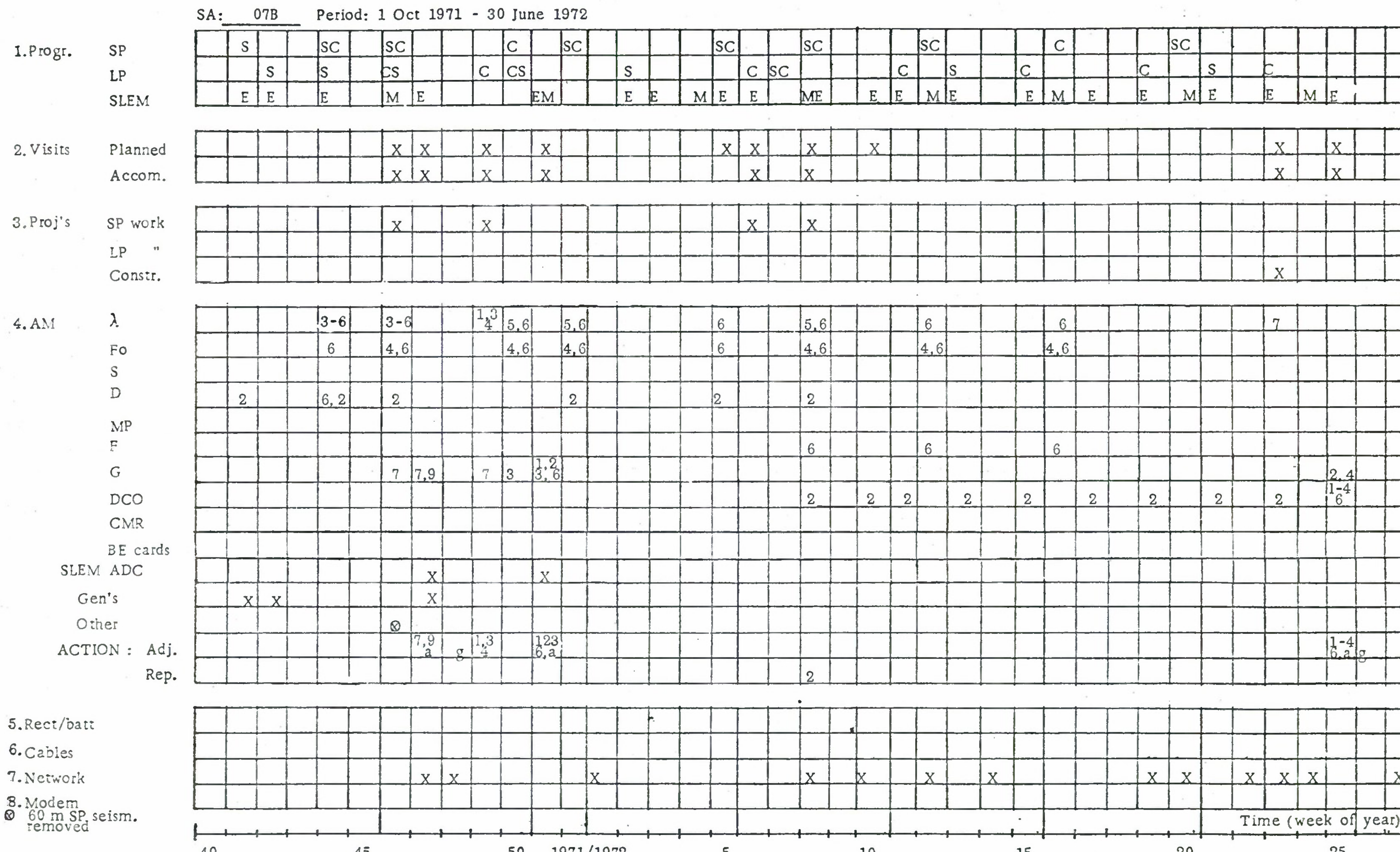
CODES

Programs: C - CHANEV
S - SACP
M - MISNO
E - SLEMTEST

Hardware/SLEM: e - EPU
a - RSA/ADC
g - Test Generators
m - Main data cable
p - Power cable

Figure 3. 7

SUBARRAY HISTORY - Array Monitoring Disclosures

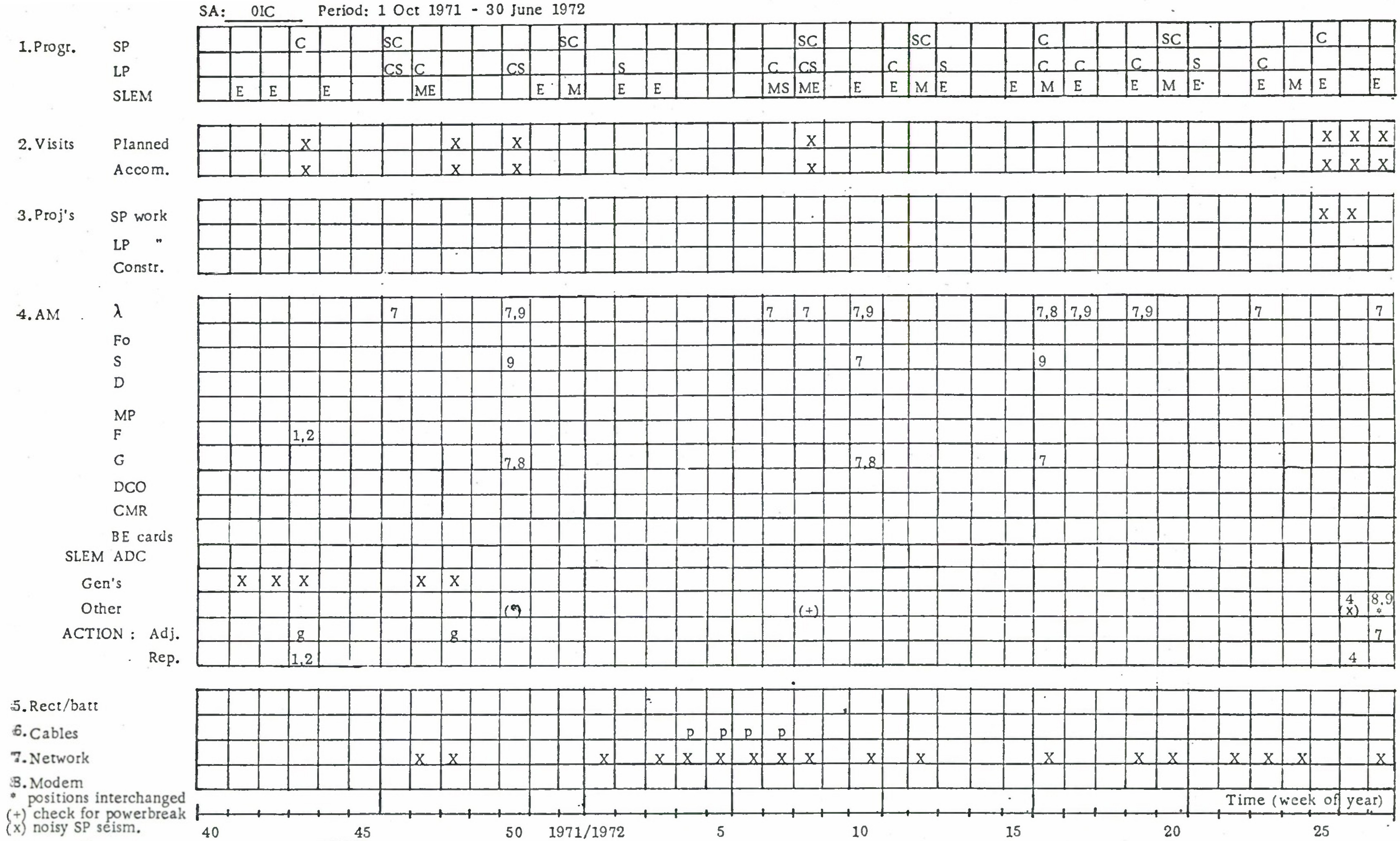


CODES

Programs: C - CHANEV Hardware/SLEM: e - EPU
S - SACP a - RSA/ADC

Figure 3.8

SUBARRAY HISTORY - Array Monitoring



* positions interchanged
(+) check for powerbreak
(x) noisy SP seism.
(*) Comparison measurements Field/EOC

CODES

Programs: C - CHANEV
S - SACP
M - MISNO
E - SLEMTEST

Hardware/SLEM: e - EPU
a - RSA/ADC
g - Test Generators
m - Main data cable
p - Power cable

Figure 3.9

SUBARRAY HISTORY - Array Monitoring Disclosures

SA: 02C Period: 1 Oct 1971 - 30 June 1972

		40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1. Progr.	SP			C	C			SC						SC					SC			SC				SC					C			SC							
	LP							CS				S				S		C		C	CS				C		S			C			C		S		C				
	SLEM		E	E		E			M				E	M		E	E		ME	E		ME		E	E	M	E			ME	E		E	M	E		E	M	E		E
2. Visits	Planned			X	X							X						X	X	X		X																			
	Accom.			X	X							X						X	X	X		X																			
3. Proj's	SP work			X	X																																				
	LP "																																								
	Constr.																	X	X	X																					
4. AM	λ				4,6			4						4,6					1,6			4			7	4				7							7				
	Fo			6	6														7-9																						
	S																																								
	D																																								
	MP											8							7-9																						
	F																																								
	G				1,6														7-9	9																					
	DCO																																		3		3		3		3
	CMR																																								
	BE cards																																								
	SLEM ADC																					X																			
	Gen's																																								
	Other																																								
	ACTION : Adj.				6,1							8							7-9			a																			
	Rep.			6																																					
5. Rect/batt																																									
6. Cables																																									
7. Network																								X		X		X	X				X	X			X	X			
8. Modem																																									

1971/1972 Time (week of year)

CODES

Programs: C - CHANEV Hardware/SLEM: e - EPU
S - SACP a - RSA/ADC

Figure 3.10

SUBARRAY HISTORY - Array Monitoring

SA: 03C Period: 1 Oct 1971 - 30 June 1972

		40					45					50							5					10					15					20					25		
1.Progr.	SP		C		C			SC						SC					SC			SC				SC					C			SC							
	LP							CS				CS				S		C			CS		C			C	S			C			C		CS		C				
	SLEM		E	E		E			ME				E	M		E			ME	E		ME		E	E	M	E		E	M	E		E	M	E'		E	M	E		E
2.Visits	Planned		X		X			X			X			X		X				X														X			X			X	X
	Accom.		X		X			X			X			X		X				X														X			X			X	X
3.Proj's	SP work		X		X			X			X																														
	LP "																																	X							
	Constr.													X		X																					X				
4.AM	λ		3,4 6		3,4			9,3			3	9							4		9	4	9			9,4				9	4		9		8,9		9				
	Fo		3,4																																						
	S																																								
	D																																								
	MP																																								
	F		2					2											2			2				2					2			2							
	G		1,2 5		3			3,4			3							9		9																					
	DCO																																						8		
	CMR																																								
	BE cards																																							4,5 6	
	SLEM ADC																			X																		X		X	
	Gen's																																								
	Other																																								
	ACTION : Adj.		346 125					3,4			3																													a	
	Rep.		3,4		3,4															a																				4,5 6	
5.Rect/batt																																									
6.Cables																																									4,5 6
7.Network						X	X		X												X	X	X					X	X				X	X			X	X			X
8.Modem																																									

1971/1972

Time (week of year)

CODES

Programs: C - CHANEV
S - SACP
M - MISNO
E - SLEMTEST

Hardware/SLEM: e - EPU
a - RSA/ADC
g - Test Generators
m - Main data cable
p - Power cable

Figure 3. 11

SUBARRAY HISTORY - Array Monitoring Disclosures

SA: 04C Period: 1 Oct 1971 - 30 June 1972

1.Progr. SP									SC				SC					SC				SC				SC				C				SC						
LP									S	C		C	S				CS		C		C				C		S		C						S		C			
SLEM		E	E		E				ME	ME			ME		E	E		ME	ME		E	EM	E			M	E		E	M	E		E	M	E		E	M		E
2.Visits Planned		X	X	X	X				X	X							X	X	X		X	X	X	X		X		X					X	X	X	X		X	X	X
Accom.		X	X	X	X				X	X									X			X	X	X		X							X	X	X	X				X
3.Proj's SP work					X																															X				
LP "																			X														X	X						
Constr.																						X	X	X											X	X				
4.AM λ										7-9		8,9	2				7-9	1	7		7,9	5			7				7								7			
Fo																																								
S					1				1				1					1				1				1				1				1		1				
D																																								
MP																																		7 *						
F																						1		1																
G			1,2 6							7.8									7.8		7.8	5				5			7					1		1				
DCO																																								
CMR																							5																	
BE cards																																								
SLEM ADC																		X	X		X	X											X							X
Gen's		X							X	X			X		X	X		X	X	X		X									X		X	X	X		X		X	X
Other									(*)																															
ACTION : Adj.			1,2 6							g									a			g	5			5							a, g	1, g		1				a
Rep.					1																	a		1										7 *		1				g
5.Rect/batt																																								
6.Cables		1	1	1																																				
7.Network																				X	X						X	X				X	X			X				
8.Modem																																								
Time (week of year)	40					45					50			1971/1972				5					10					15					20					25		

* MP lamp
(*) Check of CTV temperatures after heater installation

CODES

Programs: C - CHANEV Hardware/SLEM: e - EPU
S - SACP a - RSA/ADC

Figure 3.12

SUBARRAY HISTORY - Array Monitoring

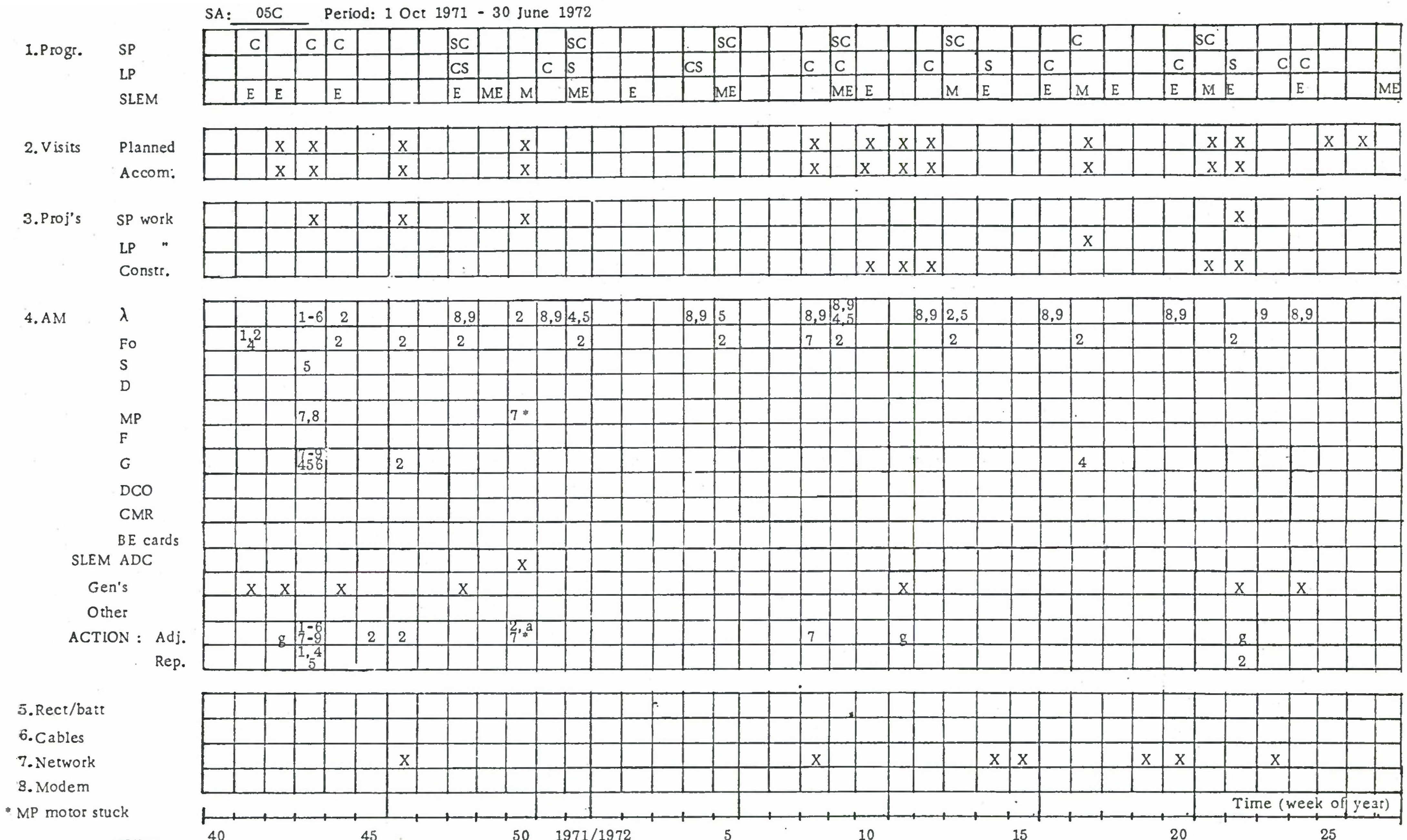


Figure 3.13

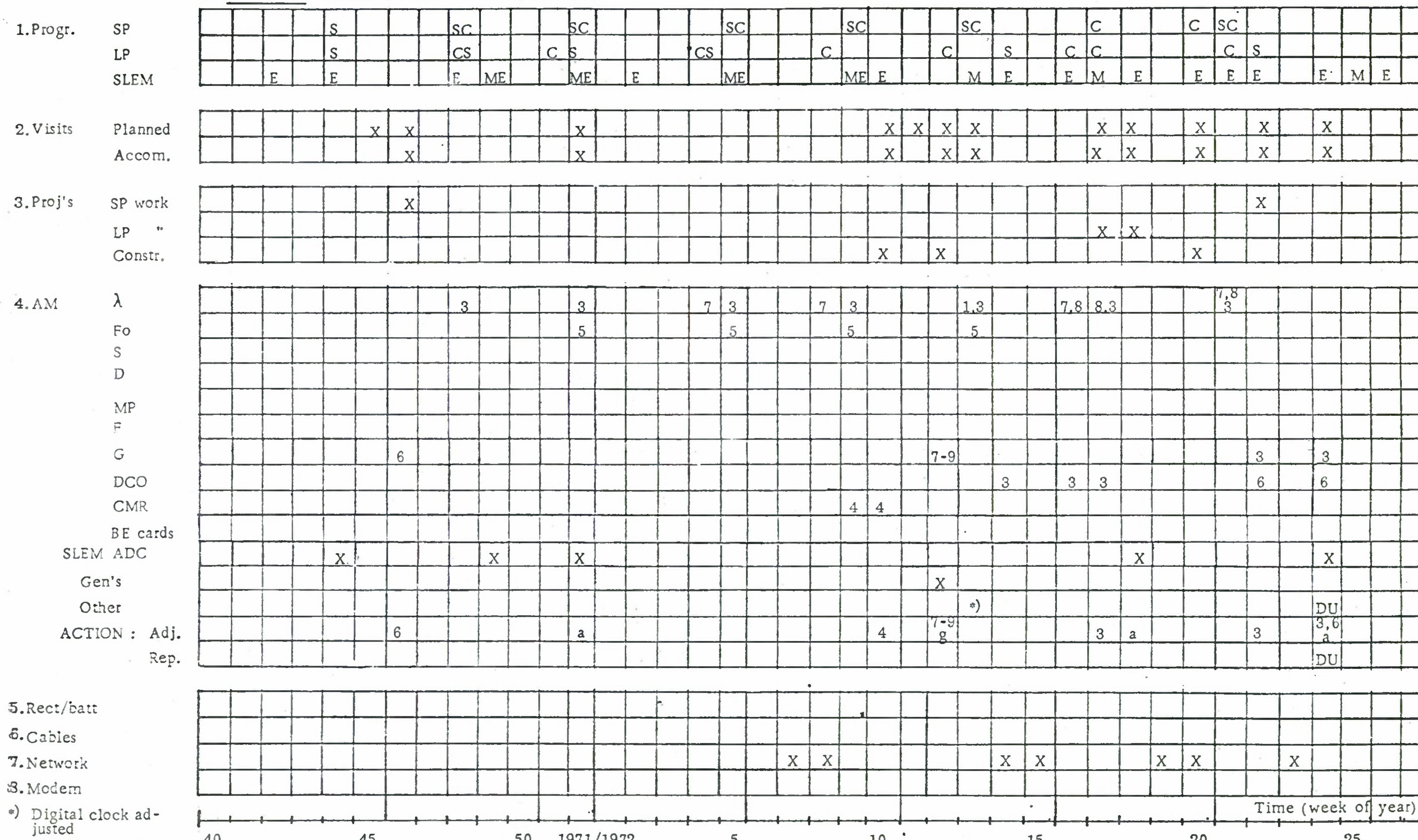
SUBARRAY HISTORY - Array Monitoring Disclosures

CODES

Programs:
- C - CHANEV
- S - SACP
- M - MISNO
- E - SLEMTEST

Hardware/SLEM:
- e - EPU
- a - RSA/ADC
- g - Test Generators
- m - Main data cable
- p - Power cable

SA: 06C Period: 1 Oct 1971 - 30 June 1972



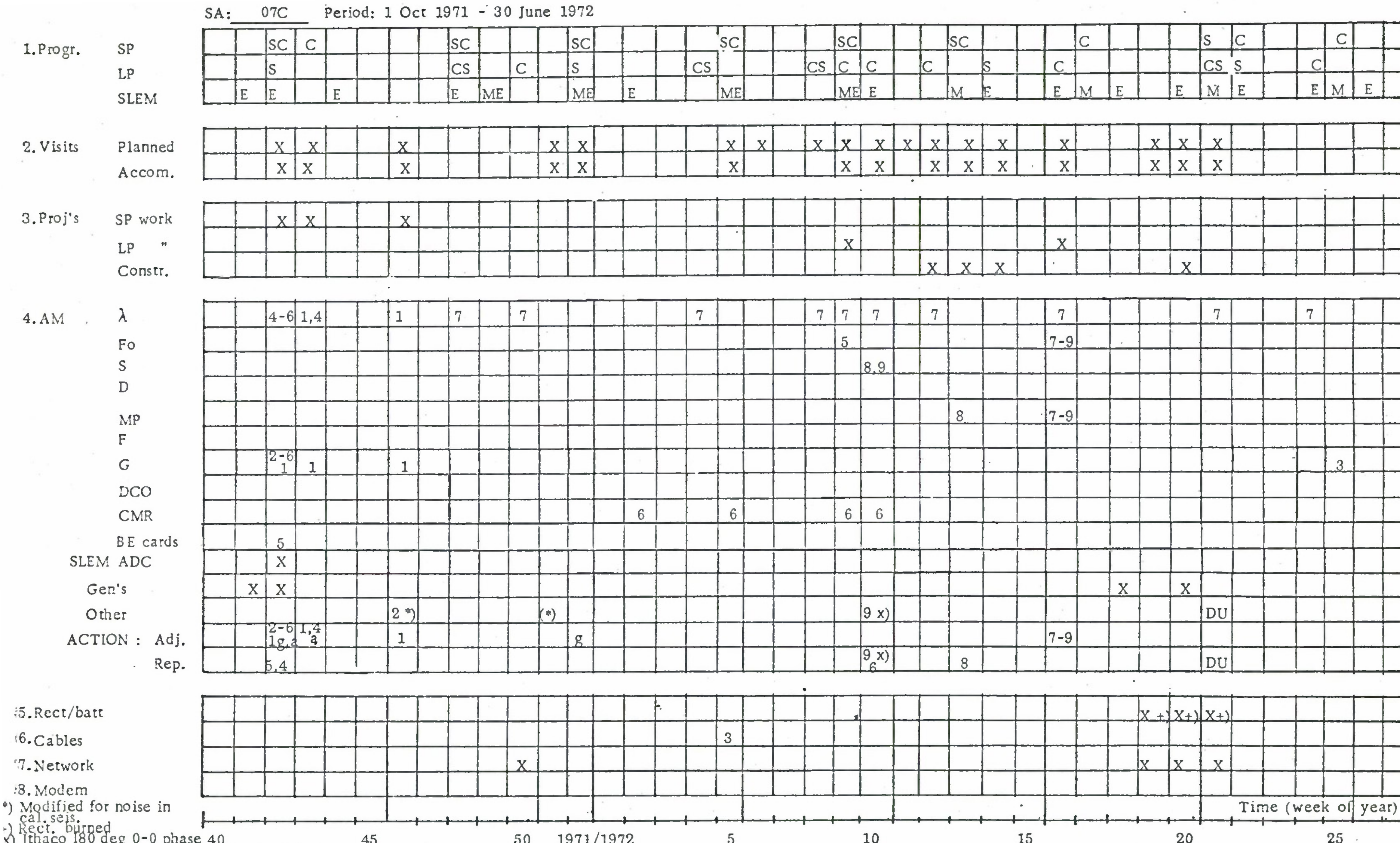
CODES

Programs: C - CHANEV
S - SACP

Hardware/SLEM: e - EPU
a - RSA/ADC

Figure 3.14

SUBARRAY HISTORY - Array Monitoring



*) Modified for noise in cal. seis.

+) Rect. burned

x) Ithaco 180 deg 0-0 phase

*) Measurements for Field/EOC comparison

CODES

Programs: C - CHANEV
S - SACP
M - MISNO
E - SLEMTEST

Hardware/SLEM: e - EPU
a - RSA/ADC
g - Test Generators
m - Main data cable
p - Power cable

Figure 3.15

SUBARRAY HISTORY - Array Monitoring Disclosures

SA: 08C Period: 1 Oct 1971 - 30 June 1972

		40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1.Progr.	SP			S		S				S	C	C		SC					SC				SC				SC				S			SC					C		
	LP			S		S				CS			C	S				CS				CS				C		S		C			C			S		C			
	SLEM		E			E				E	ME	M		ME		E			ME				ME	E			M	E		E	M	E	E	M		E		E	M	E	
2. Visits	Planned		X					X	X	X	X	X														X														X	
	Accom.		X						X	X	X	X														X															
3.Proj's	SP work		X						X		X	X																													
	LP "																																								
	Constr.																																								
4.AM	λ								1,3 6		1,4 6	14 56		4.5					4.5				4.5				6 4,5				4, 5				5				5		
	Fo		6								7	4,5							4				4				4														
	S													5					5				5				5				5				5				5		
	D																																								
	MP																																								
	F									1-8	2	2	7					7				7				7				7				7							
	G		1-5						1,3 6		1-6	1,4 5,6																													
	DCO																																								
	CMR																																								
	BE cards																																								
	SLEM ADC		X							X	X																														
	Gen's		X																																						
	Other																																								
	ACTION : Adj.		1-5 a,g						1,3 6		146 1-6	1,4 5,6																													
	Rep.		6							1*)6	7,1 5,2	5																													
5.Rect/batt											X	X																													
6.Cables																																									
7.Network												X																													
8.Modem																																									

Time (week of year) — 1971/1972

*) LTA with 8 Hz filter replaced.

CODES

Programs: C - CHANEV Hardware/SLEM: e - EPU
S - SACP a - RSA/ADC

Figure 3.16

SUBARRAY HISTORY - Array Monitoring

SA: 09C Period: 1 Oct 1971 - 30 June 1972

		40					45					50			1971/1972				5					10					15					20					25		
1.Progr.	SP										SC			SC					SC				SC				SC				C				SC				C		
	LP						S			SC	S		C	S				CS	C			CS				C		S		C				C		S			C		
	SLEM						E			E	ME			ME		E			M				ME	E			M	E		E	M	E		E	M	E		E		EM	
2.Visits	Planned		X			X	X	X		X	X		X	X					X	X	X	X											X		X	X	X	X		X	X
	Accom.		X			X				X				X								X											X				X	X			
3.Proj's	SP work									X																											X				
	LP "																																								
	Constr.																																								
4.AM	λ									1-4	4-6			1,2 5				9	1,2 5			7	12 45				1,2 5												7		
	Fo		7-9								1,5			7,1 5					12 35				12 35				1,3 5				1,5				5		5				
	S																																								
	D										4			4					4			4																			
	MP		7-9			7-9																															8, 9	9			
	F																																								
	G					9				12 45								9																			5				
	DCO																																								
	CMR																																								
	BE cards																																								
	SLEM ADC										X			X																								X			
	Gen's		X				X			X																						X	X					X			
	Other																																								
	ACTION : Adj.		7-9 g			7-9				1-4 5,g				7																			g				8,5	a,g			
	Rep.									3												4															5,9	9			
5.Rect/batt																																					X	X			
6.Cables																																									
7.Network									X	X					X							X		X		X	X				X		X	X		X	X	X			X
8.Modem																																									

Time (week of year)

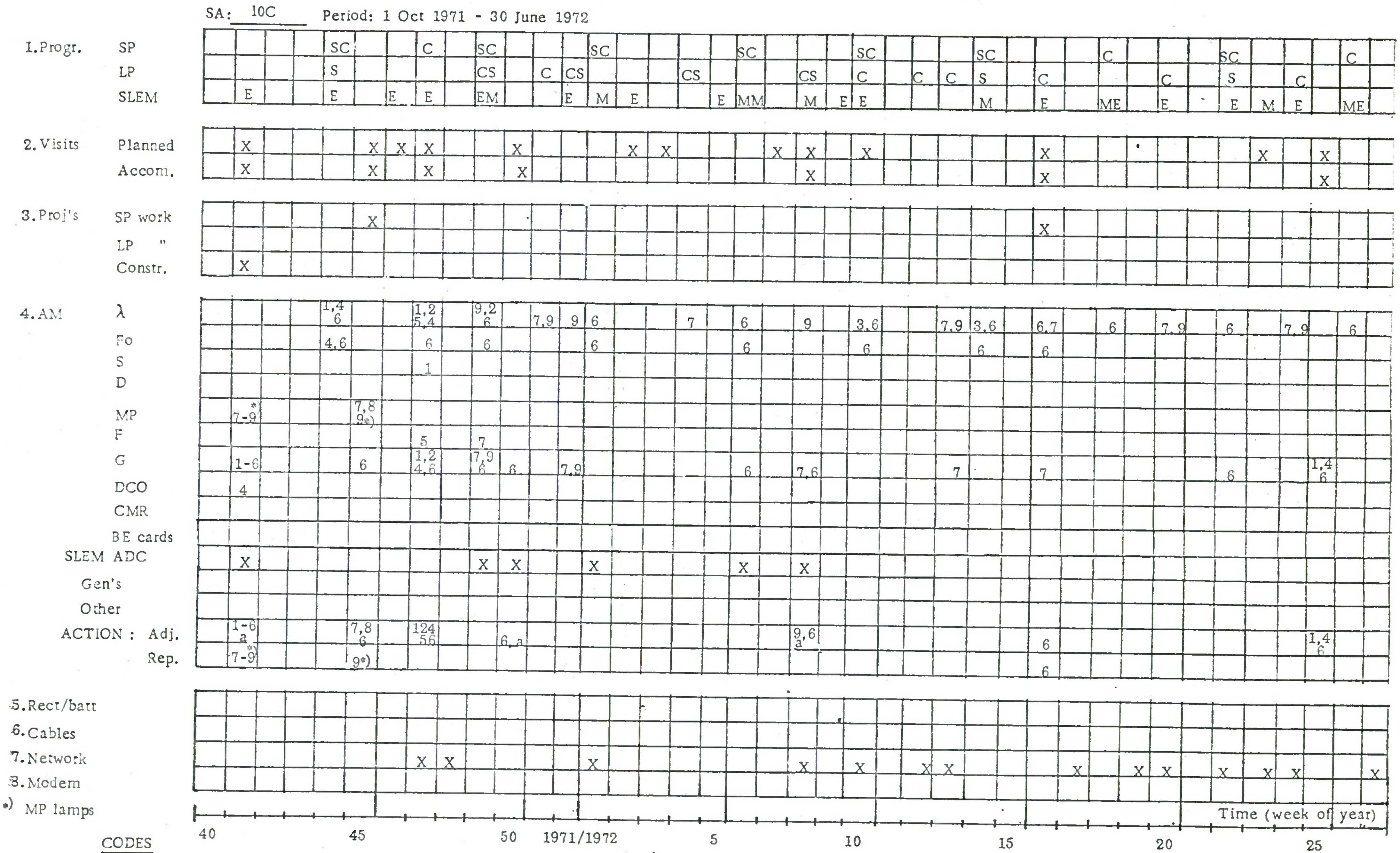
CODES

Programs: C - CHANEV
S - SACP
M - MISNO
E - SLEMTEST

Hardware/SLEM: e - EPU
a - RSA/ADC
g - Test Generators.
m - Main data cable
p - Power cable

Figure 3.17

SUBARRAY HISTORY - Array Monitoring Disclosures



CODES

Programs: C - CHANEV   Hardware/SLEM: e - EPU
S - SACP   a - RSA/ADC

Figure 3. 18

SUBARRAY HISTORY - Array Monitoring

SA: 11C Period: 1 Oct 1971 - 30 June 1972

Time (week of year), 1971:

		40	41	42	43	44	45	46	47	48	49	50	51	52
1. Progr.	SP				C	S	C				SC			
	LP					S					CS			
	SLEM					E					EM			E
2. Visits	Planned						X						X	X
	Accom.						X						X	X
3. Proj's	SP work						X							
	LP "													
	Constr.												X	X
4. AM	λ				1.2		1,4 6				9,1 7			
	Fo						1				1			
	S										7,9			
	D													
	MP						7							
	F				2.4									
	G				1						7.9			
	DCO													
	CMR						1							
	BE cards						2,3 4							
	SLEM ADC													
	Gen's													
	Other													
	ACTION : Adj.						1,2 7							
	Rep.						2,3 4							
5. Rect/batt														
6. Cables														
7. Network							X	X	X	X	X	X		
8. Modem														

Time (week of year), 1972:

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1. Progr.	SP	SC					SC				SC				SC				C				SC	C				
	LP				CS				CS				C		S		C				C		S					
	SLEM	M	E			E	M			E	ME				ME		E		ME		E		E	M	E		EM	
2. Visits	Planned		X	X				X			X						X				X		X	X		X		X
	Accom.			X													X						X	X		X		
3. Proj's	SP work																											
	LP "																											
	Constr.																											
4. AM	λ				7.8		1		7.8		1.6		7.8		1.6				1.6		7.8		1					
	Fo	1.2					1				1.6				1				1				1	1.2				
	S			7																			2 4-6					
	D																											
	MP																											
	F																											
	G				8				8,9				8				7-9											
	DCO																		6		6							
	CMR																										6	
	BE cards			2,3 4																			1			123 46		
	SLEM ADC																											
	Gen's					X					X						X		X		X		X		X	X		
	Other																							dc/ dc,e				
	ACTION : Adj.																7-9							e				
	Rep.			2,3 4,7													g						1,g	dc/ dc		123 46	g	
5. Rect/batt																												
6. Cables																						p	p					
7. Network		X		X	X				X		X		X					X		X	X	X	X	X	X			X
8. Modem																												

CODES

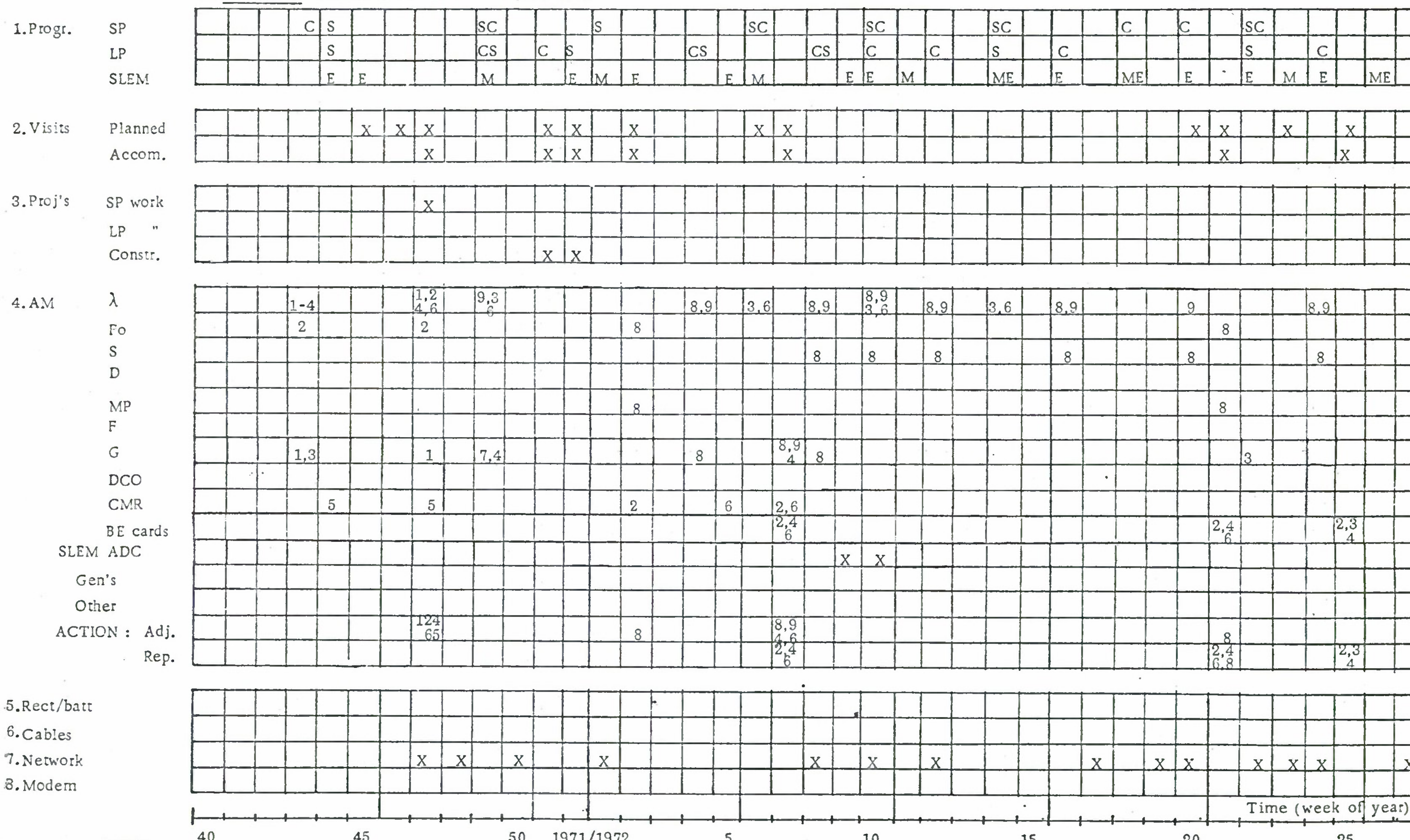
Programs: C - CHANEV
S - SACP
M - MISNO
E - SLEMTEST

Hardware/SLEM: e - EPU
a - RSA/ADC
g - Test Generators
m - Main data cable
p - Power cable

Figure 3.19

SUBARRAY HISTORY - Array Monitoring Disclosures

SA: 12C Period: 1 Oct 1971 - 30 June 1972

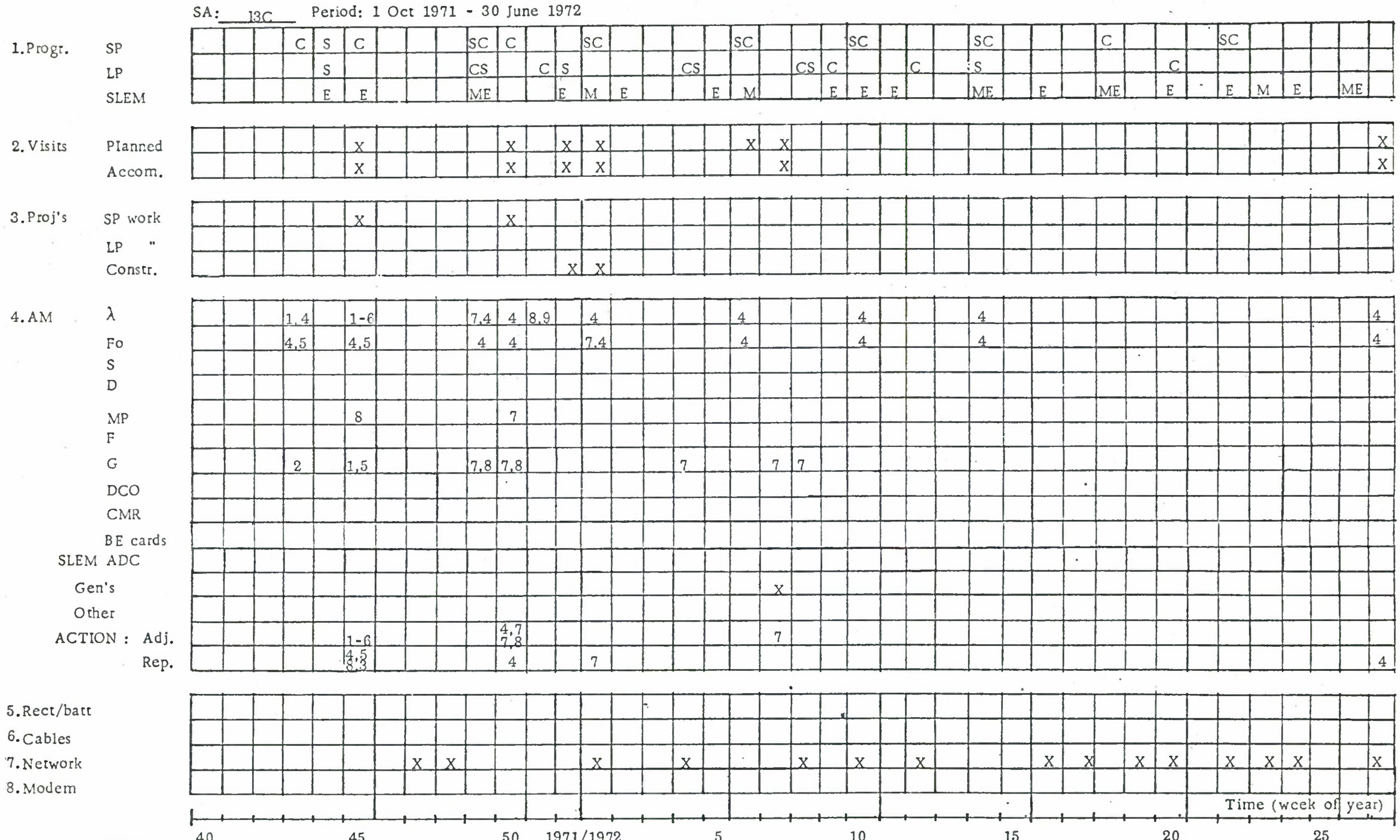


CODES

Programs: C - CHANEV Hardware/SLEM: e - EPU
S - SACP a - RSA/ADC

Figure 3.20

SUBARRAY HISTORY - Array Monitoring



CODES

Programs: C - CHANEV
S - SACP
M - MISNO
E - SLEMTEST

Hardware/SLEM: e - EPU
a - RSA/ADC
g - Test Generators
m - Main data cable
p - Power cable

Figure 3.21

SUBARRAY HISTORY - Array Monitoring Disclosures

SA: 14C Period: 1 Oct 1971 - 30 June 1972

Time (week of year), 1971/1972 (weeks 40–52 and 1–6):

		40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6
1. Progr.	SP				SC		C				C	S	C				C			SC
	LP										C	S	C	S	S		C	C	C	
	SLEM		E			E					ME			E	M	E			E	M
2. Visits	Planned			X			X									X	X	X		
	Accom.			X			X									X	X	X		
3. Proj's	SP work			X			X													
	LP "															X	X			
	Constr.															X	X			
4. AM	λ				2-6		1-6				4		4,5			4	9,5	9	9	5
	Fo				3,4						4		4			4	7-9	7,8		
	S																			
	D				5															
	MP			7-9													8,9	7-9		
	F				2															
	G			9,1; 2,4									5				7-9 4,5			
	DCO				7													7-9		
	CMR																			
	BE cards																			
	SLEM ADC															X				
	Gen's		X	X			X													
	Other																			
	ACTION : Adj.			7-9 124g			1-6									a,g	7-9 4,5	7-9		
	Rep.						134 5g									4				
5. Rect/batt							X									X				
6. Cables																				
7. Network									X	X					X					
8. Modem																				

Time (week of year), 1972 (weeks 7–27):

		7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1. Progr.	SP				SC				SC								SC					
	LP		CS				C		S				C		C		S					
	SLEM			E	E	M			ME		E		ME		E		E	M	E		ME	
2. Visits	Planned																			X		
	Accom.																			X		
3. Proj's	SP work																					
	LP "																					
	Constr.																					
4. AM	λ		9		5		8,9		5													
	Fo																					
	S																					
	D																					
	MP																					
	F																					
	G																					
	DCO																					
	CMR																					
	BE cards																			4,5 6		
	SLEM ADC																					
	Gen's																					
	Other																					
	ACTION : Adj.																					
	Rep.																					
5. Rect/batt																						
6. Cables																			456	456		
7. Network		X	X		X	X	X				X	X		X	X		X	X	X	X		X
8. Modem																						

CODES

Programs: C - CHANEV Hardware/SLEM: e - EPU
S - SACP a - RSA/ADC

Figure 3. 22

SUBARRAY HISTORY - Array Monitoring

3.2.2.2 Maintenance visit

The objectives of subarray visits - not to mention the corrective maintenance - have been the accomplishment of tasks related to preventive maintenance (see Section 3.2.2.3), comparative measurements as part of AM system evaluation (refer (4)), research on the discrepancies between field measurements and NDPC calculations of damping ratios of LP sensors (see Section 2.1.2.7), and repair of data channel cabling (see Section 3.2.2.6). Most of these required a couple of work days per subarray.

Figure 3.23 shows the number of visits to the different subarrays in the 9-month period. Not including visits caused by troubles in the communication system, the subarrays - subarrays 03B and 03C-07C excluded - have in average been visited 9.5 times. The same number for the subgroup is 22.4. However, an investigation of the tasks accomplished at these subarrays discloses that the difference is not explained by more maintenance caused by a significantly greater instability in operating parts or a more frequent degrading of performance compared with the other. For the most part the difference was caused by maintenance of the CTV/LPV facilities (accomplished at 01A-03B and 03C-07C) and evaluation research on the LP sensors (accomplished at 01B, 03B, 04B, 03C-07C and 14C). The discrepancy between subarrays of the subgroup and the rest of the array is explained in more detail in Table 3.2.

3.2.2.3 Preventive maintenance projects

The replacement of SP seismometers with characteristics outside tolerance limits was initiated prior to this period and continued until January 1972 when the access to the WHVs became difficult. Based on our experience with

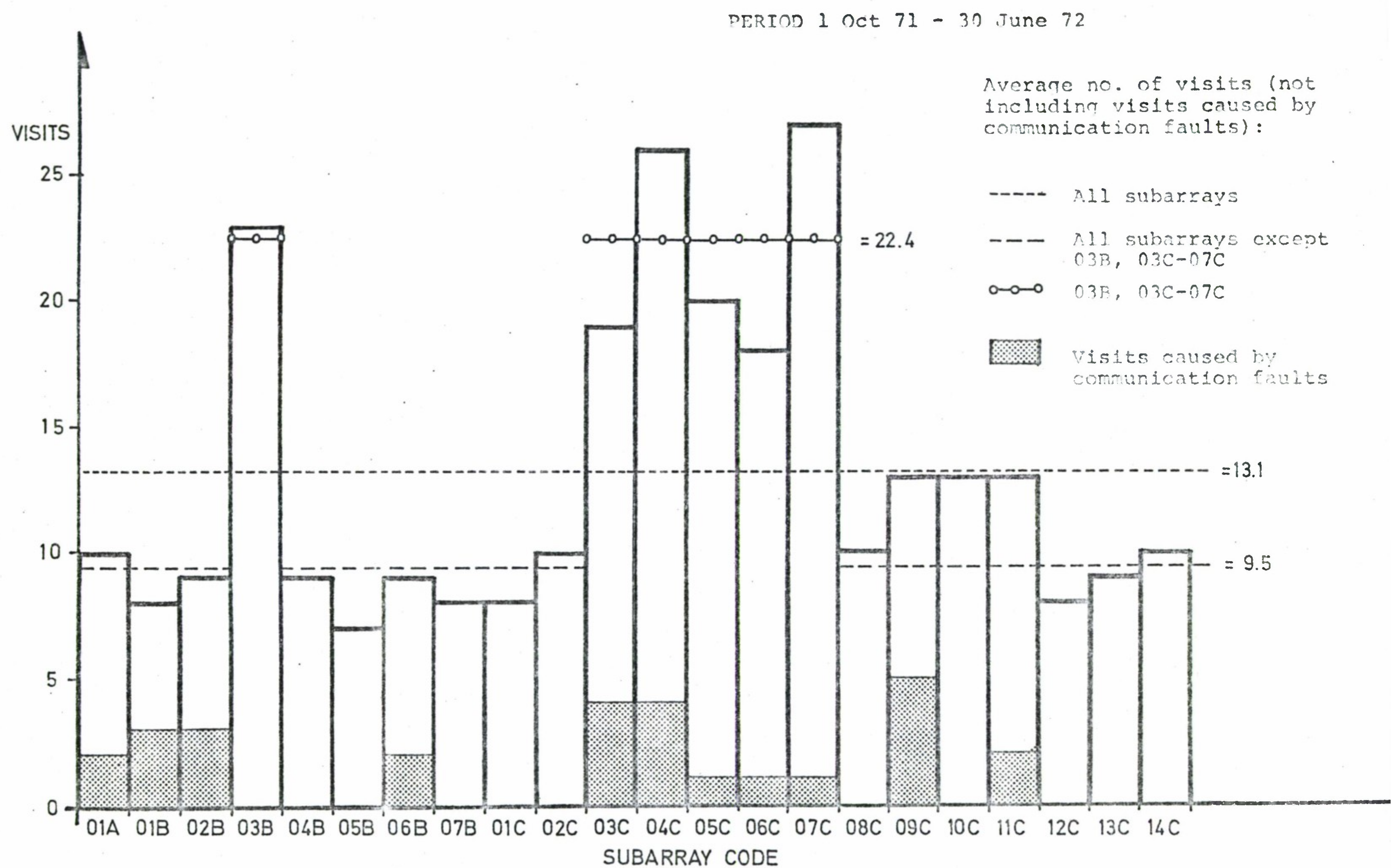


Fig. 3.23 Number of maintenance visits to the NORSAR subarrays

Sub-array	No. of visits* (Fig 3.23)	Work Days on: CTV/LPV Constr.	Field Research	Normal Main.	Comments
01A	10	4	0	6	
01B	8	3	0	5	
03B	23		8	15	9 visits: The SLEM/EPU noise degraded the timing signals in ADC
04B	9	0	4	5	
03C		7	2	10	
04C	26	7	7	12	8 visits: Cable breakage.
05C	20	9	0	11	
06C	18	7	3	8	
07C	27	8	4	15	4 visits: Rectifier troubles

* Visits caused by communications problems are not included.

Table 3.2

Tasks Accomplished at 03B and 03C-07C.

handling and maintaining these instruments, the tolerance limits were reviewed and changed on 10 April 1972 as shown in Table 3.3. (The tolerances for NORSAR SP and LP channels are given in Appendix III.)

Characteristic	Tolerance limits	
	Previous	Present (after 10/4-72)
Damping ratio	0.65-0.75	0.60-0.80
Nat. Frequency (Hz)	0.90-1.10	0.85-1.15

Table 3.3

Previous and present tolerance limits for NORSAR SP seismometer damping ratio and nat. frequency.

Because of this change and replacements of sensors accomplished during spring/summer 1972, the number outside tolerance limits of damping and/or nat. frequency were reduced to 7 sensors at the end of the period. The status of the SP sensors concerning these characteristics as of November 1971 and June 1972 is shown in Figures 3.24 and 3.25 respectively.

Work accomplished as part of the preventive maintenance of NORSAR as defined in Section 3.2.1 is given in Table 3.4. Table 3.5 shows the natural frequency and damping ratio of SP sensors as of 30 June. The values for SP damping resistance are given in Table 3.6, updated to 31 October for the sake of convenience. This table also identifies the sensors where variable damping resistance are mounted.

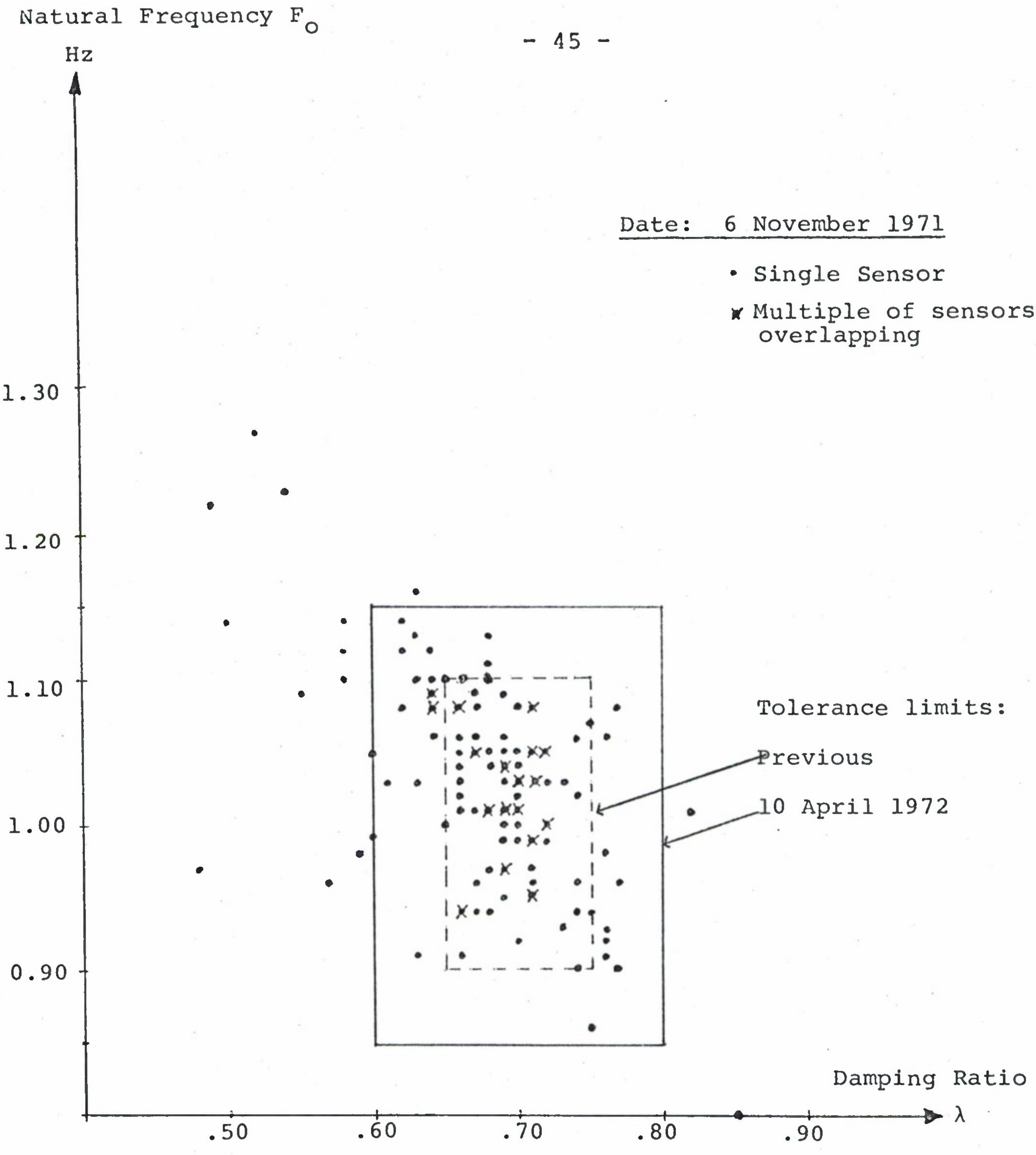


Figure 3.24 Damping and nat. frequency of SP seismometer.

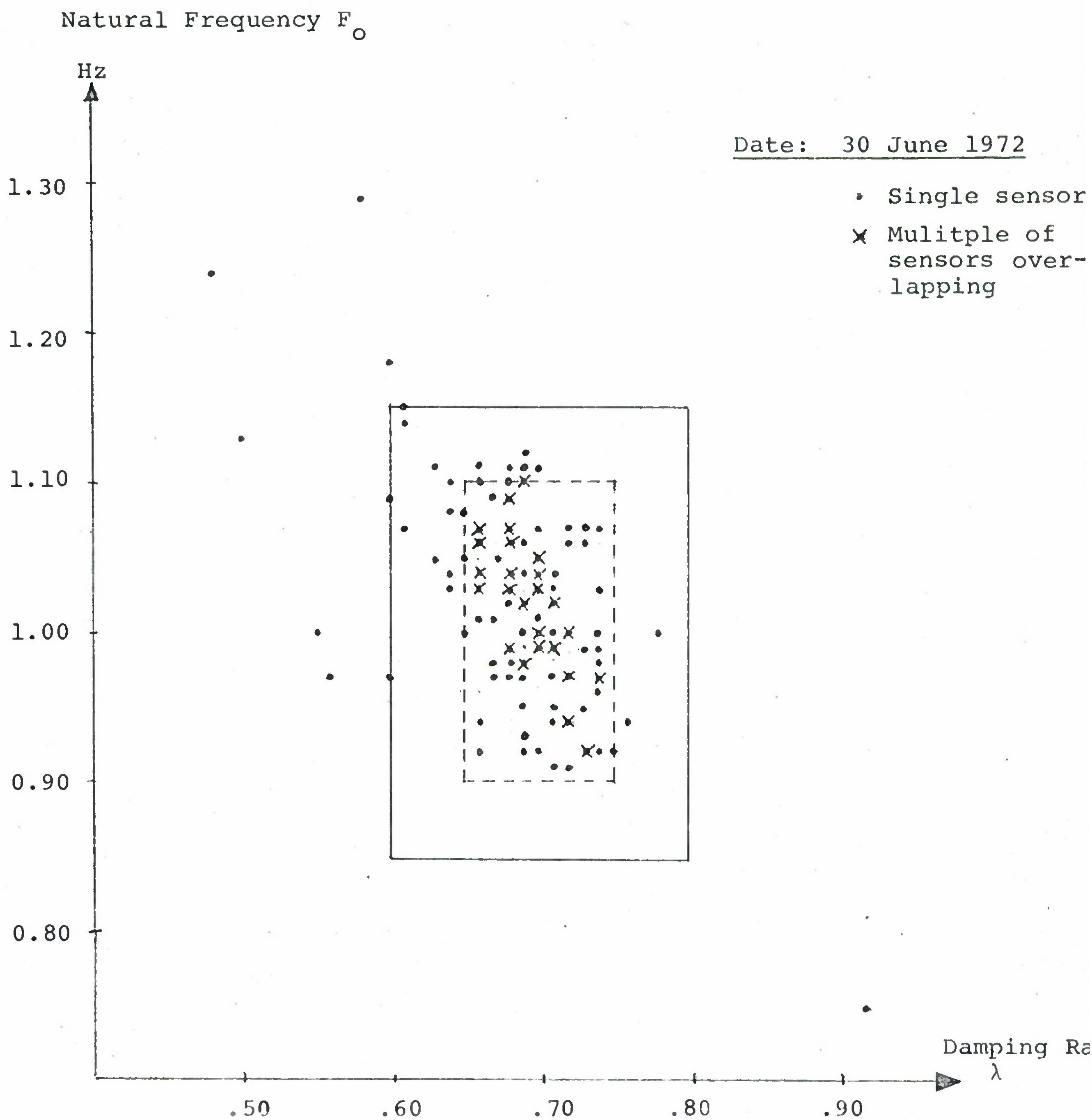


Figure 3.25 Damping and Natural Frequency of SP Seismometers.

Action	Unit	No. of Channels/ Subarrays Accompl.	Remaining	Channels	Comments
Modification of RA-5 input card	RA-5	98[1]	32[1,2]	Ref. Table 3.6	Prototype card installed at 04B and 06C (06C03 excluded).
Noise isolation	Seism	1	0	07C02	
Replacement due to λ, F_o	Seism	23	7	Refer Table 3.5 and Figures 3.2-3.25	
Construction work	CTV/ LPV	10	12	-	01A-03B,07B 03C-07C
Construction work	WHV	3		-	03C01,02,05
Removal of sensors in 60 m boreholes	Seism	8	0	-	
Pressure test	LPV	22	0	-	Leakage at 01A and 04C

1 - As of 31 October 1972

2 - Nine of these are modified for noise suppression but variable R_d is lacking.

Table 3.4 Preventive Maintenance of NORSAR Accomplished in the period.

Sub-Array	Channel	Damping Ratio	Nat. Freq.	Date Measured
01A	01	0.64	1.08	07/02
	02	0.69	1.02	
	03	0.69	1.10	
	04	0.74	0.99	
	05	0.66	1.07	
	06	0.72	1.00	
01B	01	0.68	1.07	07/02
	02	0.72	0.91	
	03	0.63	1.11	
	04	0.70	0.92	
	05	0.50	1.13	
	06	0.64	1.03	
02B	01	0.67	0.98	07/02
	02	0.68	1.06	
	03	0.68	1.11	
	04	0.68	1.09	
	05	0.69	1.12	
	06	0.66	1.03	
03B	01	0.66	1.06	07/02
	02	0.75	0.92	
	03	0.69	1.11	
	04	0.71	1.02	
	05	0.66	1.01	
	06	0.71	0.97	
04B	01	0.71	1.02	07/02
	02	0.74	0.97	
	03	0.73	0.92	
	04	0.74	0.92	
	05	0.73	1.06	
	06	0.68	0.99	
05B	01	0.71	1.03	05/05
	02	0.70	0.99	
	03	0.60	1.18	
	04	0.70	1.04	
	05	0.68	1.04	
	06	0.58	1.29	

Table 3.5 SP Natural Frequency and Damping Ratio - 30 June 1972.

Sub-Array	Channel	Damping Ratio	Nat. Freq.	Date Measured
06B	01	0.71	1.02	06/10
	02	0.68	0.97	
	03	0.69	1.02	
	04	0.66	1.11	
	05	0.70	1.05	
	06	0.68	1.03	
07B	01	0.68	1.06	06/12
	02	0.68	1.04	
	03	0.69	0.93	
	04	0.68	1.10	
	05	0.76	0.92	
	06	0.92	0.75	
01C	01	0.70	0.98	07/03
	02	0.69	0.98	-"-
	03	0.67	0.97	-"-
	04	0.68	0.99	-"-
	05	0.68	1.02	06/13
	06	0.69	1.06	-"-
02C	01	0.66	1.04	06/13
	02	0.69	1.03	
	03	0.70	1.00	
	04	0.76	0.94	
	05	0.70	1.00	
	06	0.74	1.03	
03C	01	0.71	1.00	07/11
	02	0.69	0.97	
	03	0.70	0.99	
	04	0.72	0.97	
	05	0.71	0.97	
	06	0.69	0.98	
04C	01	0.74	0.98	06/17
	02	0.71	1.04	
	03	0.68	1.03	
	04	0.70	1.00	
	05	0.71	1.02	
	06	0.71	0.99	

Table 3.5 (cont.) SP Natural Frequency and Damping Ratio - 30 June 1972.

Sub-Array	Channel	Damping Ratio	Nat. Freq.	Date Measured
05C	01	0.73	0.99	06/17
	02	0.63	1.05	
	03	0.72	0.94	
	04	0.68	0.99	
	05	0.64	1.04	
	06	0.69	0.98	
06C	01	0.71	0.94	06/17
	02	0.72	1.07	
	03	0.78	1.00	
	04	0.72	1.01	
	05	0.74	1.07	
	06	0.67	1.09	
07C	01	0.66	0.94	06/17
	02	0.66	1.06	
	03	0.72	1.00	
	04	0.73	1.07	
	05	0.72	1.06	
	06	0.72	0.98	
08C	01	0.70	1.07	06/17
	02	0.74	0.97	
	03	0.70	1.05	
	04	0.70	0.99	
	05	0.55	1.00	
	06	0.66	1.07	
09C	01	0.61	1.14	06/17
	02	0.72	0.94	
	03	0.66	1.10	
	04	0.74	1.00	
	05	0.61	1.07	
	06	0.73	0.92	
10C	01	0.69	0.92	06/23
	02	0.61	1.15	
	03	0.69	1.00	
	04	0.74	0.96	
	05	0.70	1.11	
	06	0.56	0.97	

Table 3. 5 (cont.) SP Natural Frequency and Damping Ratio - 30 June 1972.

Sub-Array	Channel	Damping Ratio	Nat. Freq.	Date Measured
11C	01	0.48	1.24	06/23
	02	0.68	1.04	
	03	0.70	1.03	
	04	0.67	1.05	
	05	0.65	1.05	
	06	0.64	1.10	
12C	01	0.69	0.95	06/23
	02	0.68	1.07	-"-
	03	0.65	1.04	-"-
	04	0.70	1.04	05/27
	05	0.71	0.95	06/23
	06	0.66	1.03	-"-
13C	01	0.67	1.01	07/07
	02	0.71	0.91	-"-
	03	0.68	1.06	-"-
	04	0.60	1.09	-"-
	05	0.65	1.08	06/23
	06	0.69	1.00	-"-
14C	01	0.65	1.00	06/23
	02	0.69	1.04	
	03	0.70	1.03	
	04	0.68	1.09	
	05	0.60	0.97	
	06	0.73	0.95	

Table 3.5 (cont.) SP Natural Frequency and Damping Ratio Status - 30 June 1972.

Sub-Array	Damping Resistance R_d (kΩ)						Updatings for Period 1/7 - 31/10 1972.
	Seismometer						
	00/06	01	02	03	04	05	
01A	250	280	X	220	180	X	
01B	X*	X*	X*	X*	X*	240	* 11/7-72
02B	X	240	X	230	210	200	
03B	205	X	X	205	X	X	
04B	255	255	295	240	320	231	
05B	X*	X*	240	X*	X*	X*	* 11/8-72
06B	240	240	240	230	200	200	
07B	200*	240*	240	290	210	280*	* 12/9-72
01C	205	250	210	280	215*	240	* 3/8-72
02C	215	X	X	240	300	240	
03C	290	XX	XX	200	240	XX	
04C	220	215	205	200	215	210	
05C	240	200	240	210	275	205	
06C	240	200	215	240	200	200	
07C	270	220	245	250	200	200	
08C	190	190	190	230	240	215	
09C	X	240	240	240	125	215*	* 18/8-72
10C	XX	240*	240	XX	XX	200	* 16/8-72
11C	XX	180	280	XX	XX	XX	
12C	210	180	215	215*	240*	XX	* 4/7-72
13C	242	205	240	215	210*	265	* 18/8-72
14C	300	180	190	200	240	240	

Codes: X - Modified RA-5 input card with variable R_d, not installed (R_d = 240 kΩ)

XX - Modified RA-5 input card <u>without</u> variable R_d installed

Table 3.6 Damping Resistance, R_d, of SP Sensors as of 30 June (with updatings to 31 October 1972).

3.2.2.4 Disclosed malfunctions - Instrumentation and Electronics

Figures 3.26 to 3.33 show the disclosed malfunctions and accomplished adjustments and replacements of field equipment with reference to the faulty channel characteristics and channel. Table 3.7 gives the number of faults in the total array classified as in Figures 3.26 to 3.33 by the involved characteristic and unit in question.

System	Action	Seismometer				Amplifier			LTA				BE card damaged	SLEM					
														Generators			ADC	EPU	DU
		λ	F_o	S	D	G	D	B	G	F	DCO	CMR		BB	SP	LP			
SP	Adjusted	55	5	-	1	9	-	7	73	-	12	4		28	5	6	30	1	1
	Replaced	4	19	3	-	-	5	2	-	12	-	2	33	5	5	5	7	5	2
LP	Adjusted	2	-	-	-	-	-	-	26	1	6	-							
	Replaced	-	-	-	-	-	-	1	-	-	-	-							

Miscellaneous:		System SP	System LP
	Faulty RCDs repaired at site		4
	RCDs replaced		12
	MP lamp bulbs replaced		5
	Replacement due to abnormal phase shift (sensor)	1	
	Replacement due to abnormal phase shift (amplifier)	1	

Table 3.7 Number and Types of Adjustments and Replacements at NORSAR in the period. (Refer to Table 3.1 for explanation of figure codes.)

Period: 1 Oct 1971 - 30 June 1972

Sub-array	Ch	Seismometer					Amplifier				LTA				BE card	SLEM					
																Generators			ADC	EPU	DU
		λ	Fo	S	D	Misc	G	D	B	Misc	G	F	DCO	CMR		BB	SP	LP			
01A	1												a		r				r a	r	
	2												a								
	3											r									
	4										a	r									
	5																				
	6																				
	V										a										
	NS	a									a										
	EW	a																			
01B	1											r				a	a		a r		
	2											r									
	3																				
	4																				
	5												a								
	6												a								
	V											a	a								
	NS												a								
	EW																				
02B	1	a									a								a		
	2																				
	3	a																			
	4	a						r													
	5	a																			
	6							r													
	V																				
	NS					2															
	EW																				

Codes: a - adjustment at site
r - replacement caused by assigned parameter
/ - refers to new unit after replacement

1 - faulty RCD repaired at site
2 - RCD replaced
3 - MP lamp bulb replaced
4 - Abnormal phase shift

FIGURE 3.26

Adjustments and replacements performed in the array by the field technicians. (Cable, modem and rectifiers repairs not included.)

Sub-array	Ch	Seismometer					Amplifier				LTA				BE card	SLEM					
																Generators			ADC	EPU	DU
		λ	Fo	S	D	Misc	G	D	B	Misc	G	F	DCO	CMR		BB	SP	LP			
03B	1										a					aa			a r a	r	a
	2										a										
	3	a					a														
	4							r													
	5										a										
	6	a					a				a										
	V																				
	NS					2															
	EW																				
04B	1																		a a	r	
	2																				
	3										a										
	4																				
	5										a a										
	6	a									a a										
	V																				
	NS					2															
	EW										a										
05B	1										a					a a		a	a a		
	2																				
	3										a										
	4										a										
	5										a										
	6										a										
	V																				
	NS					2 2															
	EW																				

Codes: a - adjustment at site
r - replacement caused by assigned parameter
/ - refers to new unit after replacement

1 - faulty RCD repaired at site
2 - RCD replaced
3 - MP lamp bulb replaced
4 - Abnormal phase shift

Parameter codes are explained in Table 3-1.

FIGURE 3.27

Adjustments and replacements performed in the array by the field technicians. (Cable, modem and rectifiers repairs not included.)

Period: 1 Oct 1971 - 30 June 1972

Sub-array	Ch	Seismometer					Amplifier				LTA				BE card	SLEM					
																Generators			ADC	EPU	DU
		λ	Fo	S	D	Misc	G	D	B	Misc	G	F	DCO	CMR		BB	SP	LP			
06B	1						a				a a					a a			r	r	
	2	r									a				r						
	3									4	a										
	4										a										
	5										a				r						
	6										a a a										
	V																				
	NS																				
	EW																				
07B	1	a									a		a			a a		a	a a a		
	2							r			aa		a								
	3	a									a		a								
	4	a									a		a								
	5																				
	6										a		a								
	V										a										
	NS										a										
	EW										a										
01C	1											r				a a					
	2											r									
	3																				
	4																				
	5																				
	6																				
	V																				
	NS																				
	EW																				

Codes: a - adjustment at site
r - replacement caused by assigned parameter
/ - refers to new unit after replacement

1 - faulty RCD repaired at site
2 - RCD replaced
3 - MP lamp bulb replaced
4 - Abnormal phase shift

FIGURE 3.28

Adjustments and replacements performed in the array by the field technicians. (Cable, modem and rectifiers repairs not included.)

Sub-array	Ch	Seismometer					Amplifier				LTA				BE card	SLEM					
																Generators			ADC	EPU	DU
		λ	Fo	S	D	Misc	G	D	B	Misc	G	F	DCO	CMR		BB	SP	LP			
02C	1										a								a		
	2																				
	3																				
	4	a																			
	5																				
	6		r a																		
	V										a										
	NS					1					a										
	EW										a										
03C	1										a								r a		
	2										a										
	3	a/aa	r r																		
	4	a	r r								a				r						
	5										a				r						
	6	a													r						
	V																				
	NS																				
	EW										a										
04C	1			r r							a/a	r			r	a a	a		a a r		
	2										a	r				a r	r	r	a a		
	3														r						
	4																				
	5										a										
	6										a										
	V					3															
	NS																				
	EW																				

Codes: a - adjustment at site
r - replacement caused by assigned parameter
/ - refers to new unit after replacement

1 - faulty RCD repaired at site
2 - RCD replaced
3 - MP lamp bulb replaced
4 - Abnormal phase shift

Parameter codes are explained in Table 3-1.

FIGURE 3.29

Adjustments and replacements performed in the array by the field technicians. (Cable, modem and rectifiers repairs not included.)

Period: 1 Oct 1971 - 30 June 1972

Sub-array	Ch	Seismometer					Amplifier				LTA				BE card	SLEM					
																Generators			ADC	EPU	DU
		λ	Fo	S	D	Misc	G	D	B	Misc	G	F	DCO	CMR		BB	SP	LP			
05C	1	a	r													a a		a	a		
	2	a a	a r																		
	3	a																			
	4	a	r																		
	5	a		r																	
	6	a																			
	V					1 1					a										
	NS										a										
	EW										a										
06C	1															a	a	a	a a a		r
	2																				
	3	r	a								a		a								
	4													a							
	5																				
	6	a									a		a								
	V										a										
	NS										a										
	EW										a										
07C	1	a a							a		a a					a a	a	a	a		r
	2				a		a		a												
	3						a		a												
	4	a							r		a										
	5						a		a		a			r	r						
	6						a		a		a			r							
	V																				
	NS					2															
	EW								r												

Codes: a - adjustment at site
r - replacement caused by assigned parameter
/ - refers to new unit after replacement

1 - faulty RCD repaired at site
2 - RCD replaced
3 - MP lamp bulb replaced
4 - Abnormal phase shift

FIGURE 3.30

Adjustments and replacements performed in the array by the field technicians. (Cable, modem and rectifiers repairs not included.)

Sub-array	Ch	Seismometer					Amplifier				LTA				BE card	SLEM					
																Generators			ADC	EPU	DU
		λ	Fo	S	D	Misc	G	D	B	Misc	G	F	DCO	CMR		BB	SP	LP			
08C	1	a r a									a					a			r a		
	2									4	a										
	3	a									a a										
	4	a a	a								a										
	5	/a/	r r								a										
	6	/aaa	r																		
	V					2															
	NS																				
	EW																				
09C	1	a														a a			a a		
	2	a														a a					
	3	a							r												
	4	a						r													
	5		r				a		a		a										
	6																				
	V																				
	NS																				
	EW					2 2					a										
10C	1	a									a a								a a a		
	2	a									a										
	3										a										
	4						a				a a		a								
	5	a									a										
	6		r						a		aaa aa										
	V					3															
	NS					3															
	EW					3 3							a								

Codes:
- a - adjustment at site
- r - replacement caused by assigned parameter
- / - refers to new unit after replacement

- 1 - faulty RCD repaired at site
- 2 - RCD replaced
- 3 - MP lamp bulb replaced
- 4 - Abnormal phase shift

Parameter codes are explained in Table 3-1.

FIGURE 3.31

Adjustments and replacements performed in the array by the field technicians. (Cable, modem and rectifiers repairs not included.)

Period: 1 Oct 1971 - 30 June 1972

Sub-array	Ch	Seismometer					Amplifier				LTA				BE card	SLEM					
																Generators			ADC	EPU	DU
		λ	Fo	S	D	Misc	G	D	B	Misc	G	F	DCO	CMR		BB	SP	LP			
11C	1	a												a	r r	r r r	r r r	r r r		a r	
	2	a													r r r						
	3											r			r r r						
	4											r			r r r						
	5																				
	6														r						
	V										a										
	NS										a										
	EW										a										
12C	1	a										r									
	2	a	a									r			r r r						
	3														r						
	4	a									a				r r r						
	5													a							
	6	a												a	r r						
	V																				
	NS					1 2					a										
	EW										a										
13C	1	a														a					
	2	a																			
	3							r													
	4		r r r																		
	5		r																		
	6	a																			
	V					2					a a										
	NS					2					a										
	EW																				

Codes: a - adjustment at site
r - replacement caused by assigned parameter
/ - refers to new unit after replacement

1 - faulty RCD repaired at site
2 - RCD replaced
3 - MP lamp bulb replaced
4 - Abnormal phase shift

FIGURE 3.32

Adjustments and replacements performed in the array by the field technicians. (Cable, modem and rectifiers repairs not included.)

Sub-array	Ch	Seismometer					Amplifier				LTA				BE card	SLEM					
																Generators			ADC	EPU	DU
		λ	Fo	S	D	Misc	G	D	B	Misc	G	F	DCO	CMR		BB	SP	LP			
14C	1	r									a					a a	a	a	a		
	2	a									a					r	r	r			
	3	a	r																		
	4		r			4					a a				r						
	5	r									a				r						
	6	a													r						
	V																				
	NS																				
	EW										a		a								

Codes: a - adjustment at site
r - replacement caused by assigned parameter
/ - refers to new unit after replacement

1 - faulty RCD repaired at site
2 - RCD replaced
3 - MP lamp bulb replaced
4 - Abnormal phase shift

Parameter codes are explained in Table 3-1.

FIGURE 3.33

Adjustments and replacements performed in the array by the field technicians. (Cable, modem and rectifiers repairs not included.)

3.2.2.5 Rectifiers/batteries

Few malfunctions on the rectifiers or batteries have been reported. Table 3.8 identifies the subarrays where faults occurred and a description of the fault.

Subarray	Fault	Period of Inoperation	Comments
07C	Transformer M2, fuse E2, gate control card U2 burned out by lightning	2-15 May	Delay due to delivery of spare parts from Siemens
08C	Resistance R1 on U3 card out of adjustment	No interruption	Charger in "High Charge" cuts out at too low battery charge
09C	Time relay faulty Coil defect	29 May - 1 June 4-6, 8-9 June	Charger permanently in "High Charge" mode
14C	D2 relay on U3 card missing	No interruption	

Table 3.8

Faults Disclosed in Subarray Rectifiers.

3.2.2.6 Cables

Cases with cable breakages have been few considering the length of the period. Table 3.9 gives the channels affected and the time elapsed before repairs were accomplished.

Sub-array	Seismometer Cable	Main Data Cable	Power Cable	Breakage (out of operation)	
				From date	To date
01C			X	17 January	11 February
01A		X		1 June	9 June
05B	02			9 June	out period
14C	04,05,06			9 June	14 June
03C	04,05,06			19 June	27 June
04C	01			6 October	21 October
11C			X	15 May	24 May

Table 3.9

Cable Breakages

3.2.2.7 Communication

Malfunctions of the modems - with only one exception for CTV-modem 01B - have all be faults related to the looping circuits or supervisory channel used for verbal communication. Malfunctioning of these does not influence the normal data transmission. They may come into effect when communication tests are initiated and result in misleading conclusions. A total of 5 occurrences of faulty looping circuits (B and C loop) and supervisory channel, all in different CTV-modems, have been reported.

As mentioned in Section 2.1.2, the frequent display of the number of detected transmission errors is a suitable tool in monitoring the performance of any NDPC/CTV communication line. The method, however, is not unambiguous. Only the number of erroneous ICW or ODW records, each of 120 bits, in the 16½ minute interval is reported - not the number of individual faulty bits. We will here define a transmission line between a CTV and NDPC as "degraded" when the error rate reported by the SPS's counter in a 16½ minute interval is higher than 20. Table 3.10 then gives the time of degraded transmission on any line relative to the operative time of DP, for three different months within the period.

Subarray	October 1971 %	January 1972 %	April 1972 %
01A	0.2	6.0	3.6
01B	0.2	50.4	3.7
02B	5.9	0.4	3.7
03B	0.2	5.6	6.3
04B	0.7	0.4	3.6
05B	0.2	0.1	2.8
06B	3.3	0.7	2.8
07B	0.2	0.1	2.8
01C	0.6	45.5	3.0
02C	0.4	0.5	4.5
03C	0.4	0.4	4.5
04C	0.3	0.5	3.7
05C	0.2	0.4	3.7
06C	0.2	0.4	3.8
07C	0.0	0.0	0.0
08C	0.0	0.0	0.0
09C	0.2	0.1	2.8
10C	0.2	0.3	2.9
11C	1.8	0.4	2.9
12C	0.3	0.1	3.0
13C	0.2	0.6	3.0
14C	0.5	0.3	3.9

Table 3.10

Time of Degraded Transmission Quality of NDPC/NORSAR Communication Relative to Operative DP Time. ("Degraded" is defined in text.)

3.2.3 Miscellaneous Maintenance

Subarray	Disclosed fault	Field Work	Symptom	Comment
01B	x		LP NS 180° out of phase	From 25 May 197 to 28 August 1972
	x		Errors in ODW test	SPS line adapte: replaced 25 Jan 1972
03B	x		Noise spikes overlayed the seismic data	EPU generated noise degraded the SLEM time pulses for the ADC .
06B	x		SP03 180° out of phase	Corrected week :
08C		x		Removal for LTA filters with 7.(Hz cut-off freq. (ch 01-06)
01A-07B		x		Removed SP sensors from deep boreholes
-	x		SP sensors reported 180° out of phase	Corrected as part of SP pre-ventive mainten-ance during fall 1971. Faulty data from 06B(0: 05C(01,02), 08C (02), 10C(02), 14C(01) are stored on NORSAF tapes.
-	x		CTV water level monitor unstable	Research initiat (see (8))
-	x		RCD locks	Research initiat (see (9))
-	x		Instabilities in RA-5	Research initiat (see (10))

Subarray	Disclosed Fault	Field Work	Symptom	Comment
-			SLEM/EPU noise	Research initiated (see (11))
07C,08C			Rectifier damaged by lightning	Research initiated (see (12))
-			Difference in field and NDPC measurement of SP damping ratio	Field measurement procedure corrected 3 November 1971
-			Noise in LP data in test mode	Refer (13). Prototype circuitry at 06C (29 Sept 1971) still mounted

Table 3.11

Miscellaneous Maintenance

3.2.4 Work Shop Repairs

Faulty units and parts removed from the array and repaired at the workshops are listed in Table 3.12.

Subarray	Unit/Channel	Week Removed	Index No. S/N	Index No. USP	Diagnostic	Parts Affected/ Repair
01A	LTA 03/04	08	-	-	Ripple	-
	EPU	09		1839	Start up circuit defective	Q3 and CR4 replaced
01B	LTA 01/02	41	-	-	DCO not adjustable	-
	ADC	03	11		Full scale not adjustable	Sent to USA for repair (warranty)
02B	RA-5 06	04		0489	Distortion	At FMC, not repaired
	RA-5 04	24	172	0491	Distortion	At FMC, not repaired
03B	RA-5 04	08	796	0485	Noise and clipping	Complete adjustment
	FP RCD N-S	19	318		Immovable	Corrosion in bronse fitting. Cleaned and lubricated
	EPU	16	4		Noise, distorting internal clock pulses	CR1 replaced
04B	FP RCD N-S	27	284		Immovable	Motor bearings cleaned, lubricated and adjusted.
	EPU	27	0002		Noisy	Main trafo T3 replaced.
05B	FP RCD N-S	10	315		Immovable	General overhaul
06B	RA-5 03	48	59	0518	Out of phase	Reversed output pair corrected
	BE 02,05	25	-	-	Low gain	Burned 100 Ω resistors replaced
	ADC	25	5208	-	Unstable	Contacts cleaned
	EPU	25	24	-	Low 6 V	Diode FD111 replaced
07B	RA-5	08	322	-	Distortion	Batteries replaced

Table 3.12

Diagnostic and Repair of Faulty Units transferred to FMC/MC.

Subarray	Unit/Channel	Week Removed	Index No. S/N	Index No. USP	Diagnostic	Parts Affected/ Repair
01C	Seism 04	26	186		Noisy	Incorrectly mounted tower
	LTA 01/02	43	-	-	Cut off frequency	-
02C	Seism 06	42	323		Natural Frequency	Adjusted
03C	Seism 03	41	121		Damping and Nat. Freq.	Main springs replaced
	Seism 04	41	554		Natural Frequency	Main springs replaced
04C	Seism 01	44			Nat. Freq. and Seis- mometer sensitivity	-
	Seism 01	23	438		Seismometer sensitivity	Pigtails too tight, seism. adjusted
	LTA 01/02	11	-	-	Cut off frequency	-
	ADC	09	413		Unstable	Connectors cleaned
	Test Gen.card	27	-	-	+BB unstable	Replaced Z7
05C	Seism 01	43	465		Nat. Freq. and damping	Readjusted and recalibrated
	Seism 04	43	367		Nat. Freq. and damping	Readjusted and recalibrated
	Seism 05	43	164		Nat. Freq. and damping	Readjusted and recalibrated
	Seism 02	22	463		Natural Frequency	Readjusted and recalibrated
06C	Seism 03	22	201		Damping	Main spring replaced
	DU	24	20		No passing of data and DI	Modules J024, J070, J090 and J100 replaced
07C	RA-5 04	42	39		Balance unstable	Trim capasitor replaced
	LTA 05/06	10	-		Common mode rejection	-
	MP RCD N-S	13	339		Motor shorted	Replaced motor
	Ithaco E-W	10	6551		Clipping and unbalance	At FMC, unrepaired
	DU	21	0001		No ADC output	Modules J024 and J090 replaced

Table 3.12 (cont.)

Diagnostic and Repair of Faulty Units transferred to FMC/MC

Subarray	Unit/Channel	Week Removed	Index No. S/N	Index No. USP	Diagnostic	Parts Affected/ Repair
08C	Seism 06	41	-	-	Seism cable broken	Replaced seism cable
	Seism 01	49	488		Damping	Main spring replaced
	Seism 05	49	431		Nat. Freq. and damping	Readjusted and recalibrated
	Seism 05	50	519		Nat. Frequency	Readjusted and recalibrated
	Seism 05	50	214		Damping	Main spring replaced
	RA-5 02	49	97		Abnormal phase-shift	Reversed output pair
09C	Seism 05	23	252		Nat. Frequency	Readjusted and recalibrated
	RA-5 03	48	-	833	Balance failure	Replaced batteries
	RA-5 04	08		605	Distortion	Replaced batteries
	MP RCD E-W	23	295		Immovable	Adjusted pressure on spindle
	MP RCD E-W	24	347		Immovable	Adjusted pressure on spindle. Cleaned & lubricated.
	Charger Unit	23			Timer defective, steady high charge	U2 card replaced
10C	Seism 06	16	40		No output	Balance spring and pigtail replaced on main coil
11C	LTA 03/04	45	-	-	Time constant	-
	BE 02,03,04	03	-	-	Low gain	Burned 100Ω resistors replaced
	Test gen. card	16	-	-	LP test gen. period	Replaced Z2
	Test gen. card	22	-	-	No 1.0 Hz output	Replaced Z1
	Test gen. card	25	-	-	-BB defective	Replaced Z7
	DC/DC Conv.	23	-	-	-	-

Table 3.12 (cont.)

Diagnostic and Repair of Faulty Units transferred to FMC/MC

Subarray	Unit/Channel	Week Removed	Index No. S/N	Index No. USP	Diagnostic	Parts Affected/ Repair
12C	LTA 01/02	07	-	-	Ripple	-
	BE 02,04,06	21	7001 7003 7007		Low gain	Burned 100Ω resistors replaced
	BE 02,03,04		7004 7007 7009		Low gain	Burned 100Ω resistors replaced
13C	Seism 04	45	449		No output	Pigtails replaced
	Seism 05	45	230		Nat. Frequency	Frequency adjusted
	Seism 04	50	196		Nat. Freq. and damping	Frequency adjusted
	Seism 04	27	392		Nat. Freq. and damping	Frequency and damping adjusted. Cable replaced
	RA-5 03	45	238		-	-
	FP RCD V	01			Immovable	Complete overhaul
14C	Seism 01	45	120		Abnormal phase shift (Data leads reversed)	Corrected
	Seism 03	45	465		Nat. Freq. and damping	-
	Seism 04	45	270		Nat. Freq. and damping	Balance spring replaced
	Seism 05	45	538		No output	Main spring, cal spring and pigtails replaced
	Seism 04	02			Nat. Frequency	-
	Test gen. card	45	-	-	LP test gen. period	Replaced Z2

Table 3.12 (cont.)

Diagnostic and Repair of Faulty Units transferred to FMC/MC

3.2.5 Drift of the Characteristics

The drift in mass position and free period of the LP sensors has been plotted. A few typical examples are shown in Figures 3.34 to 3.39. As would be expected, an abnormal drift, if any, occurs during the early spring due to tilting in the underground. No anomalies have been observed in the drift of characteristics previously discussed in this report.

PERIOD: First half of 1972 SUBARRAY: 08C

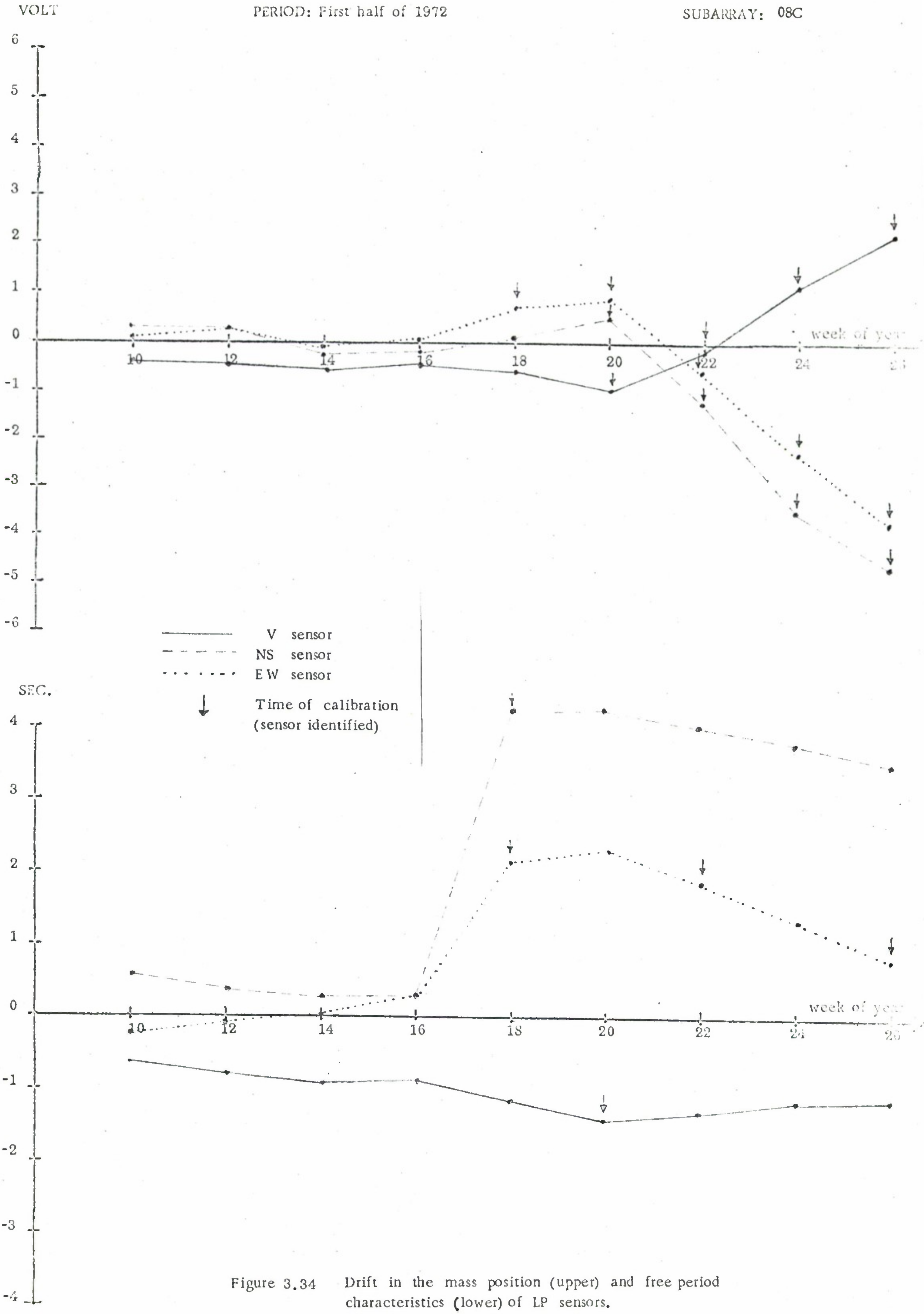


Figure 3.34 Drift in the mass position (upper) and free period characteristics (lower) of LP sensors.

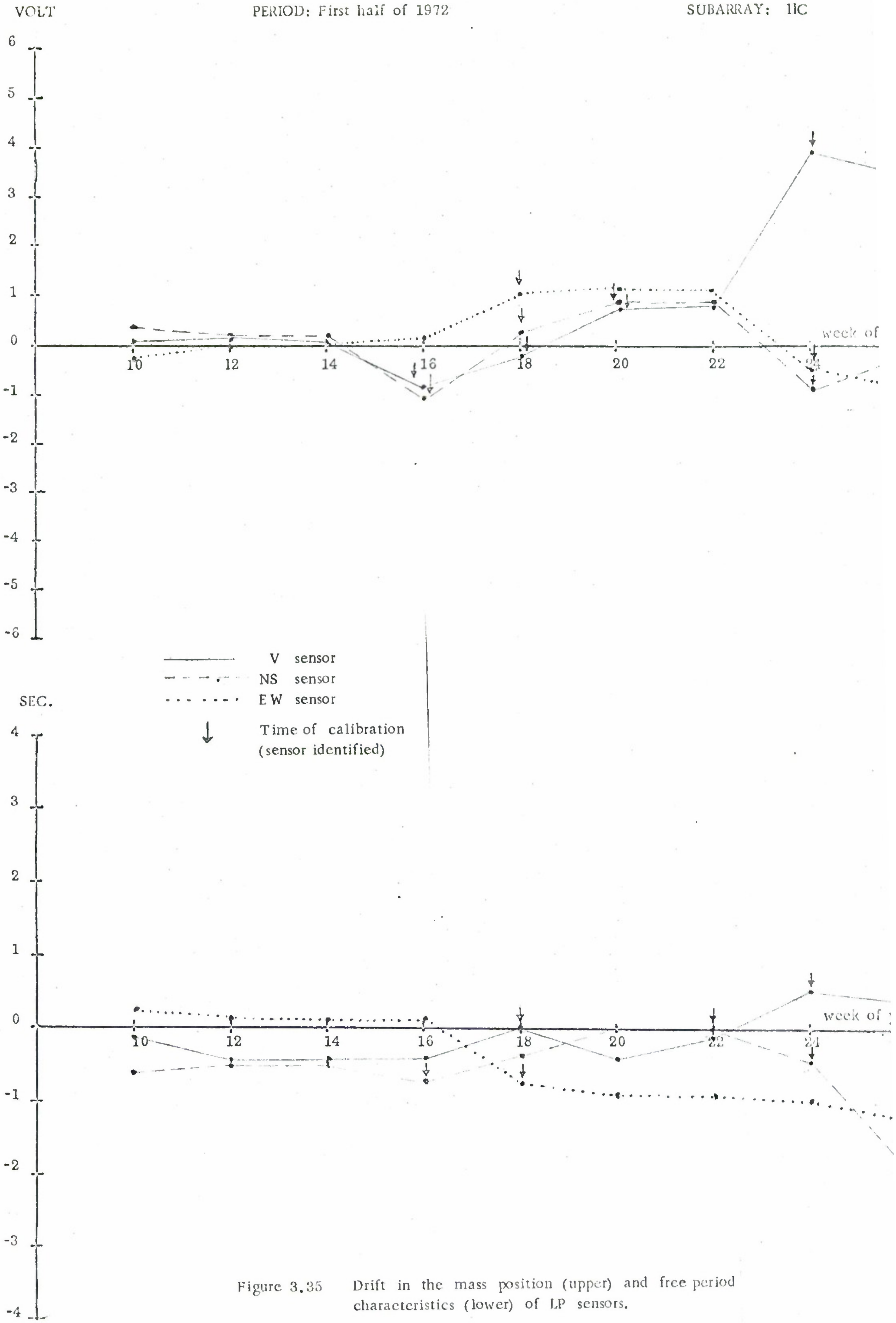


Figure 3.35 Drift in the mass position (upper) and free period characteristics (lower) of LP sensors.

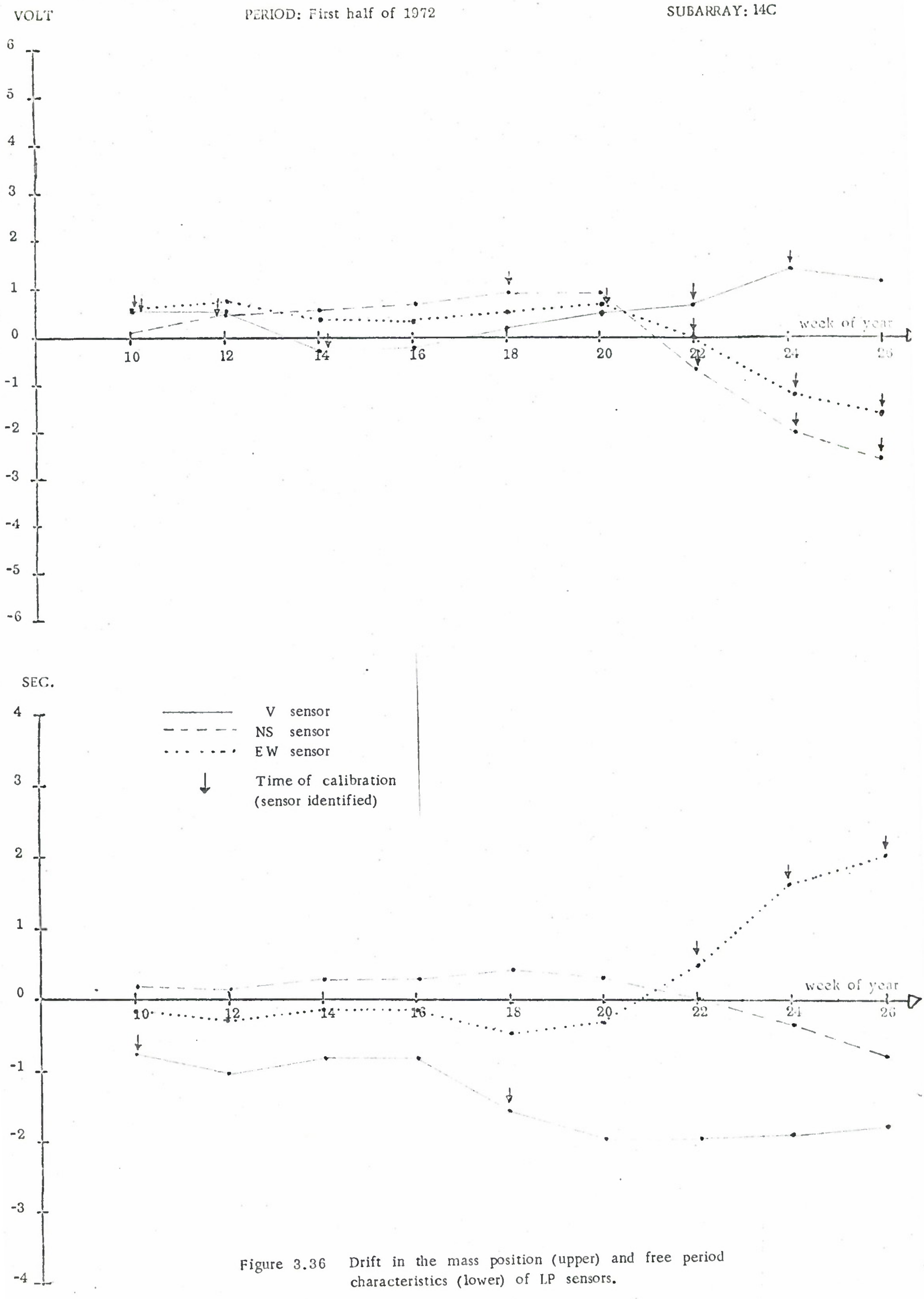


Figure 3.36 Drift in the mass position (upper) and free period characteristics (lower) of LP sensors.

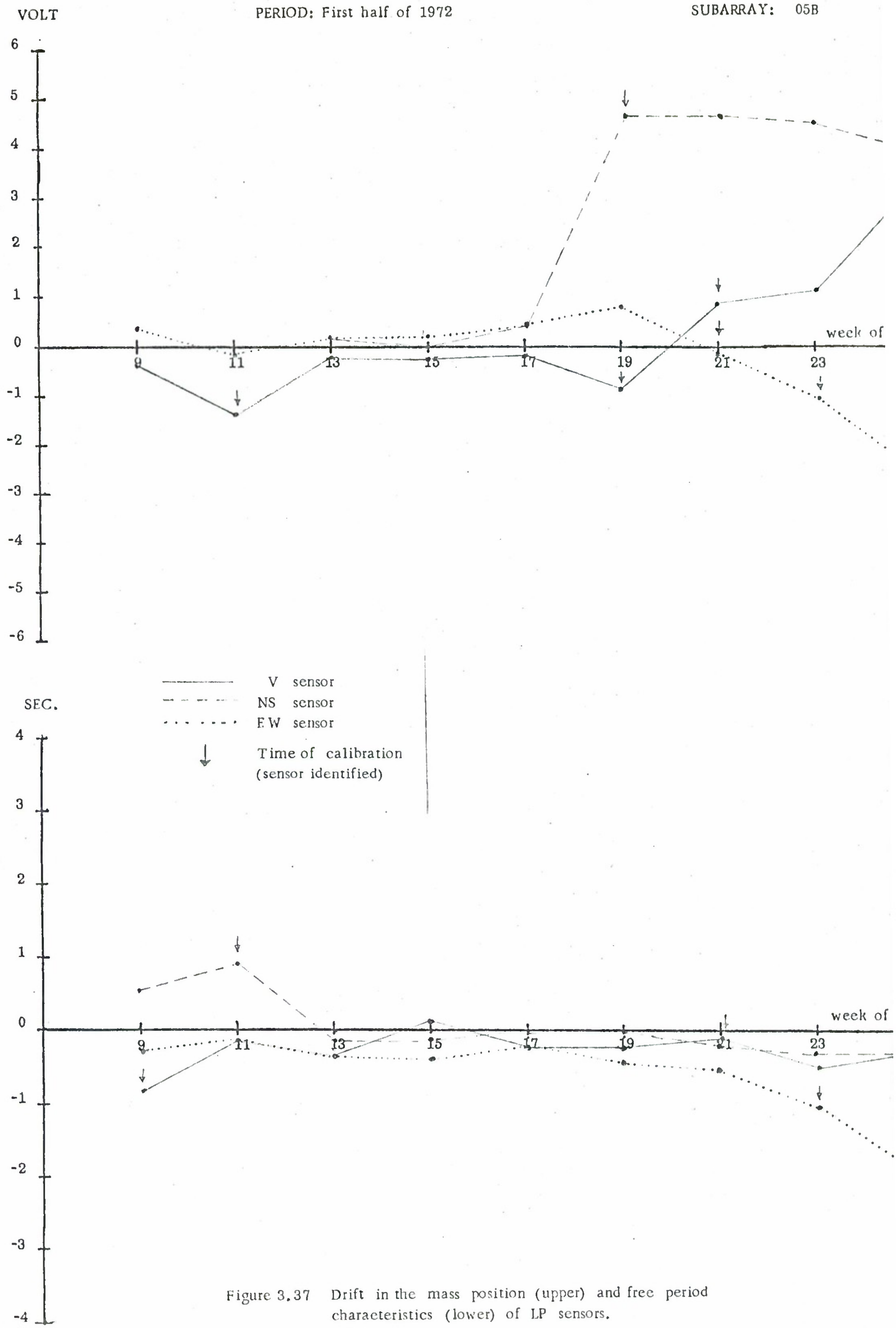


Figure 3.37 Drift in the mass position (upper) and free period characteristics (lower) of LP sensors.

VOLT PERIOD: First half of 1972 SUBARRAY: 01C

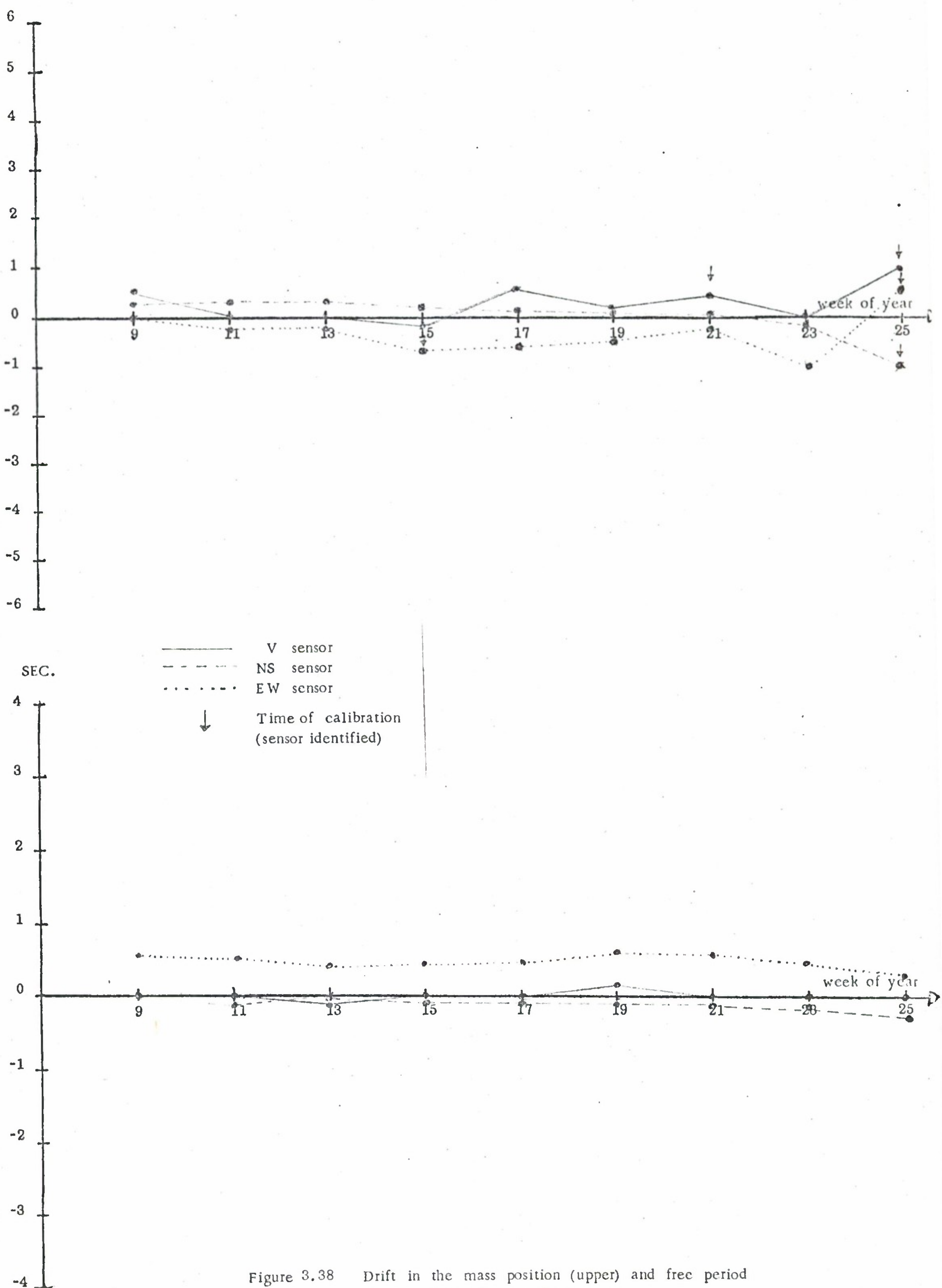


Figure 3.38 Drift in the mass position (upper) and free period characteristics (lower) of LP sensors.

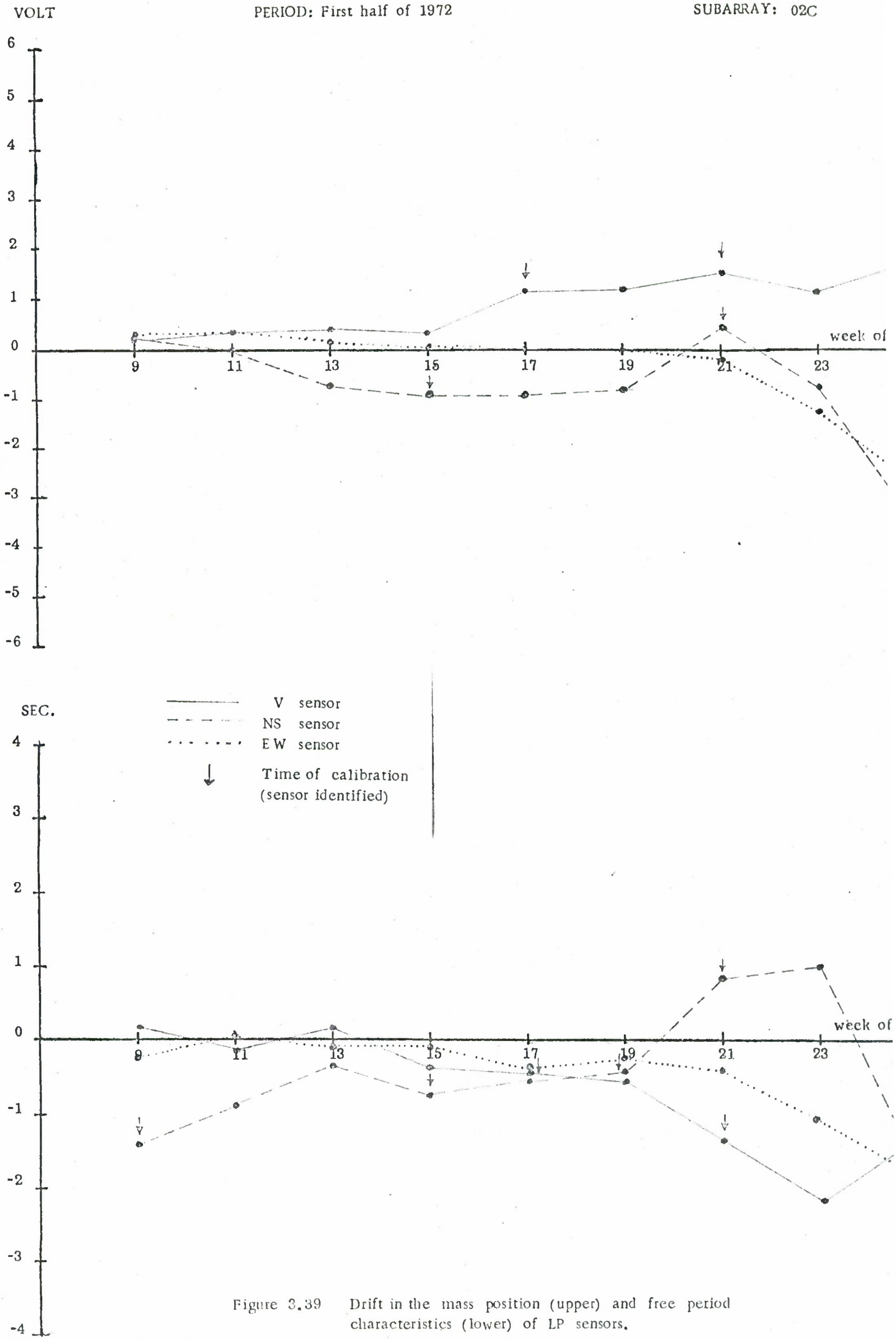


Figure 3.39 Drift in the mass position (upper) and free period characteristics (lower) of LP sensors.

4 EVALUATION

With only a few exceptions, all parts of the array field instrumentation have operated satisfactorily with less malfunctioning than expected. Referring to Table 3.7, the most sensitive parts of the system seem to be the SP seismometers and the ADCs. However, none of these are expected to cause great harm in the future, mainly because of the experiences gained in the period.

Those units which have required a high number of adjustments or replacements should be commented. The LTAs are used as channel gain adjustors. Therefore, the high number of adjustments required on these does not reflect any significant instabilities. Since the LTA logic for two and two channels is located on the same cards, the number of replacements given in Table 3.7 is twice the number of cases where replacements are required. The difference in number of adjustments on SLEM sine generators and the BB generator only reflects the fact that the tolerances for the last originally were set, and still are set, tighter than the first.

The BE cards are sensitive to lightning and the construction will be reviewed. Research will be initiated on the CTV monitor alarms which are too temperature sensitive, and on the operation of the RSA/ADC to determine if the present adjustment and replacement rate is too high and can be relaxed.

A couple of topics related to problems in different parts of the array instrumentation have been investigated in the period. This work is documented in (6) - (13).

REFERENCES

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2) NORSAR System Operation Report 1972^{I} (in print)

3) NORSAR AM Operating Plan, NORSAR Techn. Report No. 19

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5) NORSAR Field Maintenance Report for Jan-Sept 1971 NORSAR Techn. Report No. 32

6) Report on Field Adjustment of the SP Seismometers' Damping Ratio, Noratom-Norcontrol A/S

7) Suppression of SP Channel Noise, Teleplan A/S

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9) Larsen, P.W.: External Power Unit, NORSAR Techn. Report No. 27

10) Pettersen, R.: Short Description for Adjustments and Control of Rectifier, NORSAR Techn. Report No. 28

11) Larsen, P.W.: Short Description and Service Instruction for Remote Centering Device, NORSAR Technical Report No. 38

12) Hansen, O.A.: Water Detector Type AH 70 H, Short Description and Adjusting Procedure, NORSAR Techn. Report No. 39

13) Suppression of Noise in LP Channels, Teleplan A/S

APPENDIX I

AM ROUTINE PROGRAMS

1 General

The tests required for AM may be summarized in four groups. Group I tests are the automatic, continually running tests that examine the normal seismic data plus the randomly addressed data that is transmitted from the array. Group II tests require operator commands from the EOC to initiate them. Exception ICW's are transmitted from SPS to a SLEM to command the test sequence and collect the test data. Group II test data will be analyzed on-line when received at NDPC. Group III tests will collect test data as do Group II tests, but the test data will be recorded on the ISRSPS High Rate tape for later analysis by programs in the EP system. Group IV tests will be initiated from the console to provide data for operator analysis on the waveform display and/or strip chart recorder. These tests will run continuously, once started, and will terminate only on command from the operator.

2 Routine AM Programs

2.1 SLEMTEST consists of Group II tests and controls the following features of SLEM:

Test	What is tested
Data Compression Test	Data compression circuits in SLEM
D.C. Offset (DCO)	Adjustment of offset circuits in SLEM which minimize dc component in data output.

Test	What is tested
Common Mode Rejection (CMR)	Adjustment of SLEM to minimize influence of common mode signals in data output.
Channel Gain	Overall gain of a short (SP) or long (LP) period channel from seismometer to SLEM output.
Test Generator	Four test signals generated within SLEM for self-test and for test of seismometers and seismometer amplifiers.
RSA/ADC Test	Adjustment of SLEM range scaling amplifier and analog-to-digital converter circuits. Used in conjunction with missing numbers test.

2.2 CS CONTROL (Group III) consists of communication system tests:

Test	What is tested
Local Loop Test	Performance of communications link from SPS to analog side of modem located in modem room at NDPC.
Line Loop Test	Performance of communication link from SPS to analog side of modem located in CTV.
Remote Loop Test	Performance of communication link from SPS to digital side of modem in CTV.

2.3 CHANEV (Group III) consists of two programs which accomplish a frequency band analysis of SP and LP channels:

Test	What is tested
CHANEV SP	The SP channels' transfer function is determined by analysis of the channel output when a pseudo random pulse sequence is applied

Test	What is tested
	to the channel input. From this transfer function are obtained such channel parameters as filter ripple, LTA time constant, RA-5 gain, RA-5 lower 3 dB point, seismometer sensitivity, and seismometer natural frequency. The pseudo random pulse sequence is generated by the SLEM BB generator.
CHANEV LP	Similar to the CHANEV (SP) except that the LP channel transfer function and the corresponding LP channel parameters are obtained.

2.4 SACP (Group III) consists of two programs which accomplish a single frequency analysis of SP and LP channels:

Test	What is tested
SACP SP/LP	The channel transfer function at a single frequency is obtained for SP and LP channels by analyzing the channel output when a 1.0 Hz (SP) or 0.04 Hz (LP) test signal is applied to the channel input. Characteristics of the output signal such as bias, frequency, amplitude, and distortion are obtained.

2.5 MISNO (Group III)	Test the ability of the SLEM to reproduce all possible numbers within a given range. The BB generator is used to apply brief signals to the SP channels. As the signals decay samples are taken of the different levels. After many cycles of this, the numbers should all have been reproduced. It verifies adjustment and performance of the RSA/ADC circuits.

2.6 LPCAL (Group II) consists of a combination of the following tests to accomplish a calibration of MP and FP of the LP system at a subarray:

Test	What is tested
Free Period Adjust (FPA)	The FP of Long Period Seismometer is adjusted.
Mass Position Adjust (MPA)	The MP of Long Period Seismometer is adjusted.
Free Period Calibrate	Iterative executions of FPM and FPA to a set point.
Mass Position Calibrate (MPC)	Iterative executions of FPM and FPA to a set point.
Long Period Channel Noise	Measure Long Period channel seismic noise.

APPENDIX II

Instrumentation Used in Routine Workshop and Field Maintenance

Type of Unit	Manufacturer and Type Description	No. of Units
Oscilloscope	Tektronix Type 422 with battery pack	3
- " -	Tektronix Type 555 with cart, power supply and different plug-in units	1
Storage Oscilloscope	Hewlett & Packard Type 181/A	1
Display Oscilloscope	Hewlett & Packard Model 1208A/AR	1
Function Generator	Wavetek Type 116B	1
-"-	-"- 111	1
-"-	-"- 110	1
-"-	Hewlett & Packard Variable Phase Model 203A	1
Frequency Counter	Hewlett & Packard Type 5512A	1
-"-	-"- Type 5233L	1
-"-	-"- Model 5326A	1
Digital Voltmeter	-"- Type 3440	3
Plug-in Unit, multifunction for Type 3440	-"- Type 3440,Model 3444A	3
Multimeter	Triplett Type 630NA	2
-"-	Simpson Model 269-3	2
AC Transistor voltmeter	Hewlett & Packard Model 403A	2
DC Null Voltmeter	-"- Model 419A	1
AVO-meter	Electronics AVO EA113	2
P-P Voltmeter	Hewlett & Packard 1051	1
Megger	Type BM6	2
Megger	J100/1000	1

Table II-1

NORSAR Field Maintenance Instrumentation

Type of Unit	Manufacturer and Type Description	No. of Units
Cable finding equipment	Type TW5	1
Decade Resistance Box	-"- PDR5/ABCDE	2
Impedance Bridge	General Radio Type 1656	1
Attenuator Set	Hewlett & Packard 305D 5W-55V	1
Wheatstone Bridge	Yen 2755-99 N9G282	1
Decade Resistance Box	Model 1432M	1
Decade Voltage Divider	Model 1455A	1
DC Precision Voltage Source	V511N	1
Precision Power Source	Type 2005	1
Power Supply	SEEM LV40	4
-"-	Lambda	1
DC Power Supply	Hewlett & Packard 6267B	1
Power Supply	-"- 6268A	1
-"-	-"- 6289A	1
-"-	Kepco MDL (ABC10-0.75)	1
Dual Channel Recorder	Brush Type 220	3
-"-	Sanborne Model 320	1
Recorder Temperature/Humidity	Hygro Dynamics Type 15-4050E	1
Probe for above	-"- Type 15-1810	1
Digital Test Unit	Philco-Ford	2
Local Test Unit	-"-	2
Data Transmission Test Set	No 1-3	2

Table II-1
(cont)

NORSAR Field Maintenance Instrumentation

APPENDIX III

FIELD INSTRUMENTATION TOLERANCES

System	Unit	Characteristic	Nominal Value	Dim.	Tolerance	Tolerance Limits Lower	Tolerance Limits Upper
SP	Seism	Damping ratio	0.70	-	± 14%	0.60	0.80
		Natural Freq.	1.00	Hz	± 15%	0.85	1.15
		Sensitivity	32	UV/UA	± 6UV/UA	26	38
		Distortion	-	%	5%	0	5
	RA-5	Distortion	-	%	5%	0	5
		Gain	74.7	dB	± 3 dB	71.7	77.7
		Lower 3dB point	0.10	Hz	± 30%	0.07	0.13
	LTA	Distortion	-	%	5%	0	5
		Gain	-2.91	dB	± 6 dB	-8.91	3.10
		Lower 3dB point	0.038	Hz	± 33%	0.025	0.050
		Upper 3dB point	4.75	Hz	± 5%	4.51	4.99
		Upper 0.5dB point	4.30	Hz	± 5%	4.08	4.52
		Time Constant	4.30	sec	± 0.3sec	4.0	4.6
		Ripple	-	%	7%	0.0	7.0
		CMR	-	Qu	4 Qu	0.0	4
		DCO	-	Qu	16 Qu	0.0	16
	Channel Sensitivity		42.7	pm/Qu	± 10%	38.4	47.0
LP	Seism	Damping Ratio	0.64	-	± 6%	0.60	0.68
		Free Period	20.0	sec	± 0.5sec	19.5	20.5
		Mass Position	00.0	Volts	± 2.0V	-2.0	2.0
		Sensitivity	47.0	UV/V	± 21%	37.0	57.0
		Distortion	-	%	5%	0.0	5
	Ithaco	Gain	4.75 p-p	Volts	± 10%	4.27	5.23
		Distortion	-	%	5%	0.0	5
		Lower 3dB point	5.00	mHz	± 10%	4.50	5.50
		Upper 3dB point	28.6	mHz	± 5%	27.2	30.0
		Zero dB	13.3	mHz	± 5%	12.5	14.0
		Roll-off	21	dB/oct	± 1 dB	20	22
	LTA	Distortion	-	%	5%	0	5
		Gain	3.30 p-p	Volts	± 10%	2.97	3.63
		Lower 3dB point	3.73	mHz	± 6%	3.50	3.95
		Time Constant	42.9	sec	± 6%	40.3	45.5
		CMR	-	Qu	4 Qu	0	4
		DCO	-	Qu	16 Qu	0	16
	Channel Sensitivity		2.47	nm/Qu	± 10%	2.22	2.72

Table III.1
Tolerances of SP and LP Data Channels

System	Unit	Characteristic	Nominal Value	Dim.	Tolerance	Tolerance Lim	
						Lower	Upp
SLEM		SP Test Gen.	6.20 p-p	Volts	± 5%	5.89	6.
		SP Test Gen.	1.00	Hz	± 4%	0.96	1.
		LP Test Gen.	6.20 p-p	Volts	± 5%	5.89	6.
		LP Test Gen.	25.00	Sec	± 1 sec	24.00	26.
		BB Test Gen.	3.70	Volts	± 1%	3.66	3.

Table III.1
(cont.)

Tolerances of SP and LP Data Channels

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13. ABSTRACT

The improvement, maintenance and operation monitoring of NORSAR are taken care of by a department of the NORSAR project organization, headed by personnel at the NORSAR Data Center. The monitoring of the array performance is done remotely, at the Data Center, using a program package with a large number of on-line and off-line features. The report, covering the period 1 October 1971 - 30 June 1972, discusses the field maintenance of the array, the remote array monitoring and their interaction. The routines for the maintenance and monitoring tasks, and the monitoring program package are described. With only a few exceptions, all parts of the array field instrumentation have operated satisfactorily with less malfunctioning that expected. The most sensitive parts of the system are the SP seismometer and the A/D converters.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT